Handbook for Integrating Risk Analysis in the Economic Analysis of Projects

May 2002

ISBN 971-561-458-2
Publication Stock No. 060202

Published by the Asian Development Bank
P.O. Box 789, 0980 Manila, Philippines

Foreword

This Handbook is an output of a study undertaken by the Economics and Research Department (ERD) of the Asian Development Bank (ADB). Nigel C. Rayner directed the conduct of the study, assisted by Anneli Lagman-Martin. Overall supervision of the initial stages was provided by David Edwards, then Assistant Chief Economist, while Xianbin Yao, Assistant Chief Economist, supervised the study through to its conclusion. Keith Ward (Staff Consultant) provided extensive technical inputs and advice throughout the study. Support for word processing requirements was provided by Ma. Nieva Baguisa.

Preparation of the Handbook benefited from a participatory approach through consultation meetings and individual interviews. At various stages of the study, ADB staff were given the opportunity to review and comment on the draft reports. The study benefited from substantive comments from Stephen Curry, Manabu Fujimura, and Bo Lin. The Handbook was further enhanced with the inclusion of case studies, based on work undertaken by Manabu Fujimura, Vincent de Wit, Bo Lin, William Loxley, and Keith Ward. During an in-house seminar on project economic analysis, the results of the study were disseminated and the use of risk analysis software was demonstrated.

This Handbook further develops the discussion of the principles on risk analysis that is contained in Chapter XI (Uncertainty: Sensitivity and Risk Analysis) of ADB's *Guidelines for the Economic Analysis of Projects* (1997). The Handbook contains detailed discussions of current risk analysis practice, the theory and application of various risk analysis techniques, and recommended applications for risk analysis, including a summary of typical risk circumstances on a sector-by-sector basis. To illustrate the ease of use of quantitative risk analysis software, the Handbook includes case studies based on actual ADB projects in the agriculture, education, health, and power sectors. A summary version of this Handbook is available as ERD Technical Note No. 2 Integrating Risk into ADB's Economic Analysis of Projects.

The Handbook provides guidance with respect to the integration of risk analysis in the design and analysis of projects. It also provides direction on how the analysis of risk can be used to improve the focus on poverty reduction. While the Handbook is primarily targeted to ADB staff and officials of its developing member countries, it may also be of interest to others involved in development assistance.

Abbreviations and Acronyms

ADB	Asian Development Bank
ADF	French Development Agency
CAPM	capital asset pricing model
CAMEL	capital adequacy, assets quality, management quality, earnings and liquidity
CDF	cumulative distribution function
DFID	Department for International Development (UK)
EIRR	economic internal rate of return
ENPV	economic net present value
EOCC	economic opportunity cost of capital
FI	financial institutions
FIRR	financial internal rate of return
FNPV	financial net present value
NPV	net present value
PBL	policy-based lending
PFI	Private Finance Initiative (UK)
PIA	policy impact analysis (matrix)
PIR	poverty impact ratio
PPTA	project preparatory technical assistance
RRP	report and recommendation of the President
SAR	staff appraisal report (World Bank)
SERF	shadow exchange rate factor
SI	sensitivity indicator
SV	switching value
UK	United Kingdom
VaR	value at risk
VOC	vehicle operating cost
WTP	willingness-to-pay

Contents

1

Introduction and Background

Introduction

The purpose of this Handbook is to support the development of a practical and operationally relevant methodological framework for the analysis of risk in project design and project economic analysis.

The Handbook is divided into five parts. Following a brief introduction, including a summary of the reasons why risk analysis may be undertaken, Part II outlines the available technical approaches to modeling risk within conventional project economic analysis. The classic distinction between “risk” and “uncertainty” is explained, and then some typical techniques for dealing with uncertainty are outlined. This is followed by a summary of the nature and practice of sensitivity analysis in dealing with uncertain outcomes, as it is applied by, for example, the Asian Development Bank (ADB) and the World Bank (WB). Techniques for modeling risk on the basis of probability distributions are then described. This leads inevitably to questions of how to make choices among different risky investment possibilities (i.e., different projects or alternative designs of similar projects) that may have been identified through the application of such techniques. It will be noted that while there was quite a large academic literature on risk analysis in the 1970s (following the publication of the classic texts on project economic analysis in the 1960s and 1970s), there have been relatively few theoretical developments in recent years.

Part III reviews the practical experience of ADB and other major agencies with regard to the analysis of risk in project design. Some 50 ADB projects (across all sectors and from a number of countries over recent years), and a number of World Bank projects where risk analysis of different sorts has been applied (including some which are suggested to be representative of "good practice" in this regard) are reviewed. Consideration is also given to the practices of risk analysis by several other bilateral agencies, most notably the Department for International Development (DFID) of the United Kingdom (UK), and also to the UK Treasury in the application of the private finance initiative (PFI) in project design.

Part IV considers the implications for risk analysis of ADB's increasing emphasis on distribution and poverty impact analysis. As a guiding principle, it is suggested that increased lending to particular groups in society (notably the poor) now provides an imperative to extend the incorporation of risk analysis in project economic analysis. This is not only because targeting the poorest may be inherently more uncertain than reaching other groups, but also because the risks of project failure are more concentrated within society, and that the consequences of project failure can be more extreme to those at or below poverty lines. It is argued that practical applications of more rigorous risk analysis (i.e., by better incorporating planners' and project participants' awareness and perceptions of, and attitudes to, risk in project design) during investment preparation can strengthen projects as well as policy-based lending. This is expected to lead to better project selection in both cases—by both better identifying and quantifying sources of variability and by choosing project designs which meet poor peoples' aspirations and more closely fit their circumstances.

Finally, Part V provides practical guidance on how to apply different types of risk analysis in different situations, based on existing techniques and given the emerging nature of ADB's operations. Different sorts of lending are considered in relation to real-world situations with respect to data availability, time and resource implications, etc. Some practical guidance with applying software packages like the '@RISK' is provided.

Various supplementary materials are contained in the Appendixes, including brief case studies of computer-based risk analysis applied to recent ADB projects. The case studies are designed to highlight major features and key technical points—extending the original project materials in a demonstration context rather than necessarily a project-specific one.

Background

Johnson (1985) reviewed ADB's practice (and also that of the World Bank) with respect to the application of risk analysis. This paper provided a comprehensive and thorough review of literature and techniques available, but noted that risk analysis in any form had only been applied in one ADB project (a port project) and two World Bank projects (a port project and a fertilizer plant project) by that date. It may be relevant to note that this was despite the fact that major writers on the advocated techniques—e.g., Reutlinger, Pouliquen—were either World Bank staff, or were published by that institution).

The paper discussed the difficulties in obtaining reliable data in many circumstances (such that variables could be adequately described by different sorts of probability distributions), highlighted the statistical complexity of the techniques (particularly as regards dealing with covariance among variables), and noted the demands in staff and computer resources (mainframe, at that time) for undertaking risk analysis. There was also an inference that a spurious precision may appear to be attributed to results arising from risk analysis which was in reality based only on analysts' "best guesses" for variables' distributions rather than historical evidence. Also, an apparent methodological rigor in the appraisal process (as implied by a full-scale risk analysis) might actually obscure the search for radical project or policy alternatives.

Of the reviewed ADB and World Bank projects in the 1985 paper, it was also striking to note that the causes of differences between expectations (i.e., the modeling of the situation *ex ante*) and outcomes (i.e., the review of the situation *ex post*) had not been especially well-captured by the scope of the specific risk analyses which had been employed. The review also quite correctly pointed out that even where risk analysis was undertaken, in itself it did not provide a basis for choice among competing acceptable projects [i.e., among projects with net present value (NPV) > 0 at 12% discount rate] unless something was known about a society's social welfare function and extent of risk aversion—which in practice is still not likely to be available to analysts and planners today.

In conclusion, the paper recommended an extremely pragmatic approach to the use of risk analysis, suggesting that only certain sorts of situations were likely to be suitable for application of probability-based techniques. Practical applications of risk analysis in ADB project work did not appear to change significantly after the preparation of the review.

ADB's *Guidelines for the Economic Analysis of Projects* (1997)—hereafter the *Guidelines*—built upon the contents of the earlier review, and recommended the application of quantitative risk analysis techniques for situations where

- projects are very large (from a national point of view), or
- projects are marginal [i.e., where the economic internal rate of return (EIRR) may be just over 10-12%], or
- there is considerable uncertainty over the values for key variables.

Quantitative risk analysis involves consideration of a range of possible values for key variables (either singly, or in combination), which then results in the derivation of a probability distribution of a project's expected economic net present value (ENPV) or EIRR (i.e., as opposed to a single point value). The key point for analysts and planners to consider is the likelihood of a project's ENPV falling below zero (at a 12% discount rate) or its EIRR falling below the economic opportunity cost of capital (EOCC). This information should be incorporated into the decision as to whether to accept or reject the project. However, no decision rules are offered in this regard

> "There is no fixed criterion for using such a result." (*Guidelines*, Appendix 21, page 157)

as it is implicitly recognized that actual choices among differentially-risky projects will still depend upon particular levels of risk aversion being applied by different decision-makers.

Risk analysis is presented in the *Guidelines* largely as an extension of sensitivity testing, and it is suggested that such analysis should be conducted where sensitivity testing has shown that project returns are highly dependent upon the values which may obtain for a particular variable. The data requirements to undertake some sort of risk analysis (i.e., to allow the construction of some sort of probability distribution) are mentioned, but not described in depth.

The *Guidelines for the Financial Governance and Management of Investment Projects Financed by the Asian Development Bank* (hereafter, *Financial Guidelines*) also take a very similar approach to analysis of unknown financial outcomes. The analysis is seen largely in terms of sensitivity testing, and the advocated techniques are such that standard changes (e.g., +/- 10% or 20% for values of critical financial cost and benefit items, delays in implementation of one or two years, etc.) are measured in terms of their effects on estimates of financial internal rate of return (FIRR), financial net present value (FNPV), etc., and sensitivity indicators (SI) and switching values (SV) calculated for each variable tested. In almost identical format to the *Guidelines* (i.e., for economic analysis), the *Financial Guidelines* mention the possibility of quantitative risk analysis and describe circumstances in which it may be appropriate (i.e., for large, marginal or very uncertain projects), but provide no description of particular techniques.

Where the *Financial Guidelines* do differ from the *Guidelines* in their analysis of risk, however, is in their analysis of financial institutions (FIs) which may participate in ADB investment projects. When assessing FI performance, a range of standard accounting and financial measures is used, which includes indicators designed to assess risk. The *Financial Guidelines* therefore describes and advocates the use of risk measures such as credit at risk, value at risk (VaR), foreign exchange risk, maturity risk, and contagion risk. These are conceptually probability-based, although the actual data upon which they are calculated may come from entirely objective sources (e.g., historical data series) or can result from largely subjective assessments [e.g., of project preparatory technical assistance (PPTA) consultants, ADB staff] depending upon individual country and project circumstances. In addition to these financial measures, some development agencies (e.g., the French Development Agency - AFD) use systems of indicators (covering management practices, monitoring and evaluation systems, compliance with regulations, etc.) to assess exposure to risk of FIs as a result of endogenous rather than exogenous factors. Although these measures are available to project designers, actual practice suggests that use is not made of them as much as might be expected (they are typically considered in larger, ‘financial sector’ operations, rather than for smaller projects – e.g., for agriculture banks, microcredit/credit unions, etc.). It will be suggested later that their selective extension and wider application to other typical sorts of project institutions (e.g., executing agencies in transport, power, water and sanitation projects, etc.) may assist with ensuring greater sustainability of project effects (as the ultimate realization of economic benefits often depends upon the operating performance of such institutions).

One reason for the relative paucity of material on risk analysis in the *Guidelines* (and *Financial Guidelines*) is that economic theory suggests that for governments undertaking many independent projects simultaneously the consequences of risk on any one project can be ignored – risks will be “spread” across all members of society and "pooled" across the portfolio of all projects – and thus the government can be taken to be 'risk neutral' as far as individual projects are concerned. The original conceptual basis for this argument was established in a classic article by Arrow and Lind (1970). However, to the extent that project lending may tend to become concentrated on specific sections of society (i.e., particular groups—including the poorest in society, individual regions, certain sectors, etc.) the burden of risks becomes more concentrated within society and these general assumptions begin to break down.

As will be described in Part III of the Handbook, actual applications of risk analysis in ADB operations have remained relatively limited since 1985, and have been concentrated in certain sectors, notably power. One reason for this situation has undoubtedly been difficulties for staff and consultants with obtaining reliable data about key variables, and also having easily available computer software capable of fitting probability distributions (e.g., normal, uniform, log-normal, binomial, beta, exponential, etc.) to data sets and generating expected values (e.g., for project ENPVs, EIRRs, etc., and also for absolute values in the context of cost-effectiveness analysis) with associated measures of variance.

While the fundamental issues concerning data (and the extent to which situations can be described as "risky" as opposed to simply "uncertain") remain and are germane to individual project situations, considerable advances in computer software in recent years mean that (where data are available) risk analysis can now be undertaken extremely easily as an "add-in" to existing, predominantly spreadsheet-based, financial and economic analysis at any stage of project preparation. Some forms of risk analysis can also be undertaken within existing spreadsheet software (e.g., Lotus, Excel)—not even requiring any add-ins.

A survey of commercially available risk modeling software (Mariano 2001) concluded that [among several competing packages, including 'Crystal Ball, 'RiskEase' (updated version of 'RiskMaster'), @RISK] the @RISK package (Professional Edition, and an add-in to Microsoft Excel) was highly suitable for

- undertaking "Monte Carlo" based simulations to derive probability distributions of outcomes (including of project EIRRs/ENPVs)
- fitting distributions to data sets (using advanced algorithms), and
- viewing graphically the distributions of variables and outcomes.

The implication is therefore that the tools for at least some types of risk analysis are now potentially widely available (and indeed one software package for dealing with risk in this way, i.e., "Risk Master" has already been applied within ADB). The question remains as to how and in what circumstances such tools may be advocated as appropriate to be applied much more widely.

Why Undertake Risk Analysis?

Before considering in some detail the various techniques available for risk analysis, it may be worth reviewing exactly what the purpose of applying any such techniques really is.

Much of the discussion in project economic analysis texts and in academic literature concentrates on the outputs of quantitative risk analysis (i.e., 'expected' EIRRs/ENPVs plus associated measures of variance) as being useful for making choices between different investment projects (i.e., projects with higher expected returns but more variability of returns may be compared to less attractive but more stable opportunities). Following on from this, it is demonstrated that understanding a decision-maker's (i.e., planners, policy-makers, society) subjective attitude towards risk—how higher expected returns are traded off against increased variability—enables consistent choices to be made across a portfolio of public sector investments.

In practice, however, ADB is typically not concerned with making choices among a number of mutually-exclusive, competing projects but is more usually engaged in reviewing projects one-by-one. For this reason the analysis of risk through the techniques described below is practically of most use in

- identifying those factors (e.g., quantities, prices, rates of adoption and usage) which are the key determinants of project outcomes
- determining the likelihood of an individual project's returns being unacceptable (i.e., EIRR<EOCC, ENPV<0) because of the effects of the identified key risk factors, and
- designing measures within that project environment and its sector context to mitigate the identified risks arising from the identified key factors.

The emphasis and presentation of any form of risk analysis in project economic analysis observed in practice is thus usually on demonstrating that risks to individual project success have already been identified and mitigated as far as possible within the proposed project design, and that the extent of any remaining risk is both quantified (i.e., known) and its existence is regarded as 'acceptable' (i.e., to ADB, borrowing government, project beneficiaries, etc.) given the nature of the particular intervention proposed. The risk analysis techniques are thus essentially used to complement sensitivity testing in demonstrating project robustness.

It is also the case that comprehensive analysis of project risks helps in designing projects so that different parties (e.g., borrowing government, operating entity, private operators) can share and manage risks appropriately. In general, the principle to be followed is that the parties who can best manage different sorts of risks to projects (e.g., construction costs, operating costs, defaults, delays, etc.) should be allowed to reap the rewards or bear the costs of risk management. Where project environments include a private sector participant (e.g., in running a toll road, building a hospital), appropriate consideration of all risk types enables them to be shared among the participants; this type of analysis has been particularly well-developed within the UK Treasury PFI methodology.

Therefore, although risk analysis (of whatever particular form) may typically appear at the end of an economic analysis in a typical Report and Recommendation of the President (RRP), it should be noted that, from ADB's perspective, risk analysis is fundamentally a project design tool. It is not simply an afterthought to economic analysis.

2

Technical Approaches to the Analysis of Risk in Project Economics

Introduction

This part of the Handbook provides a summary of available techniques for dealing with the outcomes of unknown events in project design and economic analysis.

It begins with a conventional definition of the terms “risk” and “uncertainty”. This is then followed by a summary of methods for dealing with the existence of project outcomes which can only be modeled as uncertain, rather than risky. This includes (but is not limited to) techniques already applied as standard practice by ADB. It then summarizes the techniques available for modeling risk on the basis of probability distributions (this is the most widely understood area of risk analysis), and highlights both advantages and limitations of such approaches.

This is followed by consideration of issues involved in modeling what are sometimes called "subjective" attitudes to risk—i.e., risk as perceived (for example) by those investing in or affected by a proposed project. This is an important aspect of risk analysis in project work because it is always the case that choice between alternative risky outcomes involves knowing something about decision-makers' or participants' preferences, and in particular how they are willing to trade off increased rewards against increased risks (i.e., measuring the extent of individuals' or decision-makers' risk aversion).

Risk and Uncertainty: A Definition of Terms

The term "risk and uncertainty" tends to be applied generically to the analysis of situations with unknown outcomes. This document will follow the conventional distinction between risk and uncertainty made in the literature [e.g., following Renbourg (1970) from which the quote below is taken, and also Reutlinger (1970), Pouliquen (1970), etc.].

In essence, risk is a quantity subject to empirical measurement, while uncertainty is of a non-quantifiable type. Thus, in a risk situation it is possible to indicate the likelihood of the realized value of a variable falling within stated limits—typically described by the fluctuations around the average of a probability calculus.

On the other hand, in situations of uncertainty, the fluctuations of a variable are such that they cannot be described by a probability calculus.

Thus risk and uncertainty are best thought of as representing a spectrum of unknown situations with which an analyst may be dealing, ranging from perfect knowledge of the likelihood of all the possible outcomes at one end (i.e., risk) to no knowledge of the likelihood of possible outcomes at the other (i.e., uncertainty).

It is important to realize at the outset that it is not the real-world situation itself which is either "risky" or "uncertain", but merely the information available to planners and analysts which defines it as such. All actual project outcomes are unknown, because they occur in the future and are subject to influence by a number of variables, each of which may take different values. If we have reliable historical or forecast data such that a probability distribution can be constructed for such variables, the situation can be modeled as "risky", if we do not have such data we can only describe the future in terms of "uncertainty".

In dealing with an agricultural project, for example, if historical rainfall patterns or irrigation water supply data exist we may be able to construct a probability distribution such that crop yields can be predicted in terms of expected values with associated levels of variability. If we do not have such data then possibly only "high", "likely" or "low" values for crop yields may be estimated, depending upon whether seasonal rainfall or water flow is above or below certain levels. Similarly, analysis of an energy project may be undertaken in terms of "optimistic" or "pessimistic" assumptions about domestic and commercial power demand levels (and different returns predicted under such different scenarios), or may be modeled on the basis of a distribution of outcomes of future power demand which itself depends upon estimates of economic growth, population growth, etc., and which may be described on the basis of their probabilities of occurrence. In both cases there is nothing inherently different about the circumstances of the projects themselves, only the data available to the analyst which makes modeling of risk more or less possible.

It should be noted that this distinction between risk (unknown but quantified outcomes) and uncertainty (unknown and unquantified outcomes) is not usually so clearly made in typical financial analysis. For example, the UK Treasury Taskforce on Private Initiative (2000) quotes an accounting definition of risk as follows

> "A simple definition of risk as used by the accounting profession is uncertainty as to the amount of benefits. The term includes potential for gain and exposure to loss."

Clearly such a definition blurs the distinction made previously between risk and uncertainty. It is argued that such a distinction is in fact very useful because it helps to separate those situations which may be subject to quantitative analysis from those which are not.

Allowing For Uncertainty

Project economic analysis (and the overwhelming weight of both ADB and World Bank experience) tries to allow for the existence of unknown future outcomes in the most basic sense by modeling the existence of uncertainty rather than dealing with risk *per se*.

Attempts to model the impact of uncertain outcomes and develop decision rules about what choices to make (e.g., between different projects or alternative project designs) derive from the operations research (particularly linear programming models) and game theoretic (e.g., von Neumann, Morgenstern) approaches of the 1960s and 1970s. In situations of different possible project alternatives and uncertain future events ("states of nature"), projects would be chosen on the basis of various proposed criteria, according to decision-makers' preferences. Such proposed criteria included

- "Laplace"—select the project or design alternative which yields the highest return, whatever the "state of nature" obtains
- MAXIMIN—select projects or design alternatives which yield the best returns (e.g., highest NPV) if the situation/"state of nature" turns out as badly as possible, and
- MINIMAX REGRET—select the project which minimizes the maximum opportunity cost of having made a wrong choice by choosing a "state of nature" which does not in fact obtain.

It can be shown that such criteria (and others that were developed around the same time) are in fact all "irrational" in different ways. For example, the "Laplace" criterion effectively ignores uncertainty altogether, the MAXIMIN assumes "nature" to be as malevolent as possible (which is not the case), and the MINIMAX REGRET does away with normal assumptions about decision-makers' preferences (because they are more concerned about minimizing losses *ex post* than about maximizing returns *ex ante*).

Despite some historical applications for planning purposes, for such reasons as just given, game theoretic criteria were largely abandoned as models of descriptive or prescriptive behavior, and subsequent practice in ADB and elsewhere has largely concentrated on describing unknown outcomes alone, without attempting to derive decision rules to guide choice under uncertainty.

The most widely-applied technique for describing uncertainty is sensitivity testing, and this is described in detail in the *Guidelines* (page 39, and Appendix 21), and also in the *Financial Guidelines* (section 7.11). A full explanation of the technique and its application is also provided in Belli et al's *Economic Analysis of Investment Operations* (World Bank Institute 2001).

In essence, sensitivity testing involves changing the value of one or more selected variables which affect a project's costs or benefits and calculating the resultant change in the project's NPV or IRR. Although emphases and presentation differ, both ADB and World Bank recommend practices such as:

- testing for the effects of changes in aggregate project costs and benefits
- testing for the effects of changes in individual underlying variables (e.g., areas, yields, crop prices in an agricultural project; prices of cement, operating costs of machinery in a roads project; consumer utilization rates

in a power or water supply project, etc.). This choice of variables will usually be based on previous similar project experience and/or detailed sector knowledge as much as on the particular project in question
- testing variables one at a time, so as to be able to identify the ones with most impact on project NPV
- testing for delays in benefits or implementation (e.g., shift the benefits stream down a year or two)
- testing likely combinations of variables (especially if these may in practice be linked —e.g., project costs go up AND implementation delays simultaneously occur), and
- testing for changes in economic pricing adjustments (e.g., shadow wage rate factor, shadow exchange rate factor, standard conversion factor, etc.) made by the analyst.

Sensitivity testing leads to the calculation of switching values (SVs) and sensitivity indicators (SIs):

- SV identifies the percentage change in a variable for the project NPV to become zero (i.e., for the project decision to switch between "accept" or "reject", average yields would have to fall by 20%). Sometimes SVs are expressed in terms of the absolute value of a variable—e.g., "if passenger traffic volume fell to 15,500 vehicles per day the project would not be viable"
- SI compares the percentage change in a variable with the percentage change in a measure of project worth (e.g., NPV).

The prime utility of sensitivity testing is that it leads to the identification of those variables to which a particular project design is most sensitive, and mitigating action can then be taken (if desired) to minimize the consequences of such outcomes. Likely mitigating actions include undertaking pilot projects, securing long-term supply contracts (for inputs and/or outputs), increasing technical assistance and training levels to support project implementation, publicity campaigns to promote service usage, tax and tariff changes, etc. The technique is extremely easy to apply, as changes to one value in a spreadsheet will reflect instantly in values for NPV, IRR, etc.

However, the technique has a number of limitations:

- most fundamentally, it does not take into account the probability of the occurrence of the events it models. The SV for crop yields may be a fall of 20%, or that for traffic flow may be 15,500 vehicles per day, but how likely is it that either or both will occur in practice?

- where deviations from project "base case" estimates are modeled in sensitivity testing, it is not clear whether the variations in values which are being modeled are changes from "expected" values (i.e., the "base case" estimate of the value of the variable is its average value) or are deviations from "most likely" (or modal) values; depending upon the characteristics of particular distributions (in effect the extent of skewness in the data set), mean and modal values may be very different from one another, and what is being captured in the base case and its variation is not clear;
- the identification of appropriate groups of variables to vary together depends on specialist knowledge, and misunderstanding the nature and extent of correlation between variables can lead to erroneous results; and
- because the distribution characteristics of different variables which determine project outcomes can differ enormously (the variability in commodity prices is less than input prices for example, the variability in power demand is less than in generation, etc.), the use of standard percentages for variations (changes of +/– 10% or 20% are routinely applied for example) in sensitivity testing captures quite differential extents of likely variability. An impression of homogeneous variability is given, which is not warranted by reality.

Overall, sensitivity testing is a highly subjective technique. Its ease of application and familiarity of concept, combined with analysts' understanding of particular sectors and projects (which should lead to reasonably appropriate variable selection and extent of variation being applied) plus its usefulness in leading to development of mitigating measures and project redesign, mean that its use has become widespread. However, its dependence upon judgment rather than empirical evidence and its modeling of uncertainty rather than risk (plus its inability to offer any decision rules following the presentation of its results) mean that its usefulness as a technique is ultimately limited.

One other point may be mentioned in regard to modeling uncertainty in project economic analysis. It is sometimes suggested that uncertainty can be allowed for by either applying a different discount rate in the calculation of NPV or by using a higher cutoff rate (i.e., greater than 10-12%) for investment decisions. While there is a large theoretical literature on this point, in essence there is no justification for this approach—apart from any other consideration (e.g., in determining what an appropriate "risk premium" should be), it assumes that risk always increases with time, which is not necessarily true. The discount rate is a rate of decline in the numeraire of economic value, and has nothing to do with the source of risks facing an investment.

Modeling Risk Quantitatively

Because of the conceptual shortcomings of all approaches to modeling uncertainty, various attempts have been made to properly capture the impacts of unknown outcomes through modeling risk quantitatively in project economic analysis.

As the *Guidelines* state, the purpose of quantitative risk analysis in essence is to

> "provide a means of estimating the probability that the project NPV will fall below zero, or that the project IRR will fall below the opportunity cost of capital." *(Guidelines*, Appendix 21, page 156)

While the *Guidelines* do not themselves provide a methodology for the application of risk techniques, it is suggested that the results of sensitivity testing be used to consider which variable(s) may be appropriate to base a risk analysis upon (i.e., those that have major impacts on project outcomes). Having identified particular variables, a number of possible data points (i.e., values above and below the "base case", upper and lower limits to data values, etc.) are necessary to be specified, together with the frequency (or likelihood) of each of these values occurring. From such data points and associated frequency estimates, a probability distribution can be constructed for the variable(s) in question.

Table 1 shows the numbers of bus passengers who may be expected on a particular route per week (and which may represent, for example, usage of similar services elsewhere in the city for an earlier project). The average number of passenger bus trips is 50,000, the standard deviation (the average difference between all observations and the mean/average) is 27,386 and the coefficient of variation (the ratio of the standard deviation to the mean) is 0.547.

The figure below shows graphically a simple probability distribution (based on frequency of observations falling within particular class intervals) for the number of bus passengers, deriving directly from the data in the table.

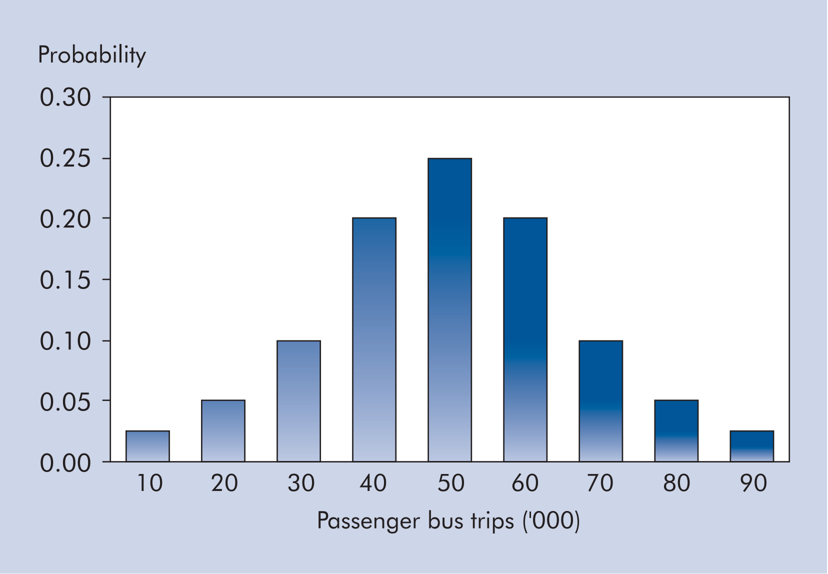
Table 1

Number of Bus Trips and Frequency of Occurrence

Number of bus trips ('000)	10	20	30	40	50	60	70	80	90
Probability of occurrence	0.025	0.05	0.1	0.2	0.25	0.2	0.1	0.05	0.025

Figure 1

Passenger Bus Trips Probability Distribution

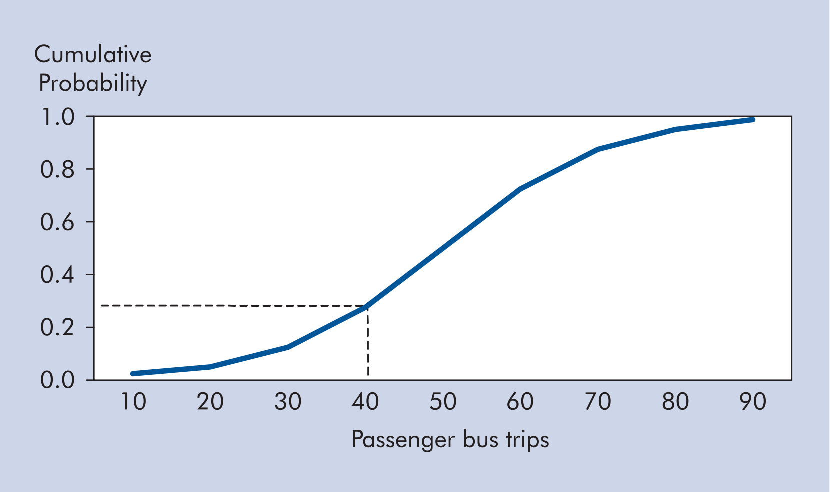


From the data, it is apparent that the expected number of bus trips is 50,000 (and this may be the basis for the estimate of the project "base case" scenario), but there is a 10% chance that the number of passengers may only be 30,000 per week, and a 5% chance that the number of passengers may only be 20,000 passengers per week.

The following figure (Figure 2) shows the same distribution in the form of a cumulative probability distribution function (which has been "smoothed" to allow for the effect of observations of grouped data). The function plots the cumulative probability that the actual outcome will be below a certain level of bus trips. It can be seen that, for example, there is a 27.5% probability that the number of bus passengers will be below 40,000 a week. In this example, actual numbers of passengers on project-financed buses each week may well determine both the financial profitability of the bus company and also the size of the economic NPV of the project. It may be the case, for example, that sensitivity testing has indicated that the SV (switching value—the value of the variable at which the project investment decision is changed) for bus passengers is at or near 40,000 per week—and we can now say what the probability is of this value obtaining. In this case, the probability is relatively high (i.e., over one chance in four), which may well imply that a redesign of the proposed project would be appropriate.

Figure 2

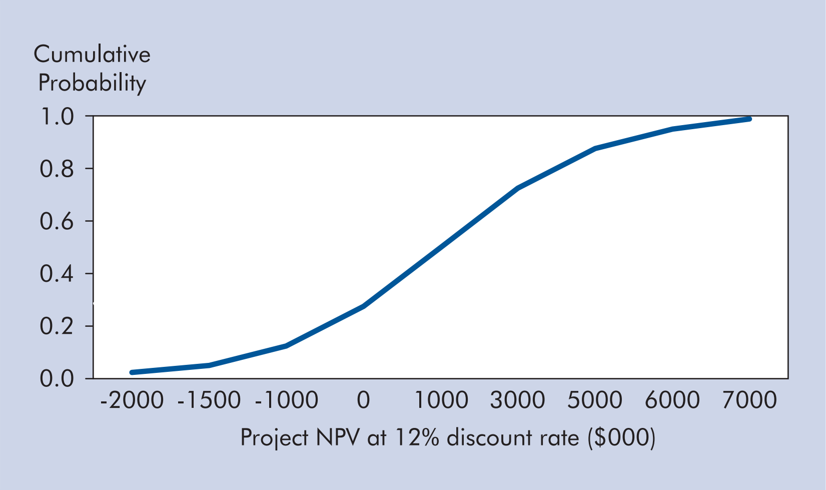
Cumulative Probability Distribution



The ultimate purpose of quantitative risk analysis is to generate a similar cumulative distribution probability function for a project's NPV, such that the probability of negative NPV being generated is explicitly identified. The following figure shows such a chart:

Figure 3

Cumulative Distribution Function



The probability of project NPV being negative as a result of variability in underlying factors is thus able to be identified (i.e., 30% in the figure), and provides further information as to the relative attractiveness (in terms of its riskiness) of the project. The same data could of course be used to model the financial profitability of the bus company in a similar fashion.

With the discussion so far, and most literature describing such techniques, it should be noted that identical procedures to these can be applied to projects where expected ENPV is not typically calculated in ADB practice (e.g., education and health projects, which tend to use measures of cost-effectiveness rather than total net economic worth). The only difference is that instead of expected NPVs would now be absolute measures of expected cost-effectiveness of outputs or impacts (e.g., annual cost per health worker employed, cost per primary school pupil educated) quoted together with distributions for those values (e.g., in 75% of circumstances the cost per health worker would be less than Baht 4,000 per year; the cost per primary school child educated would be Rupees 21,000 in four years out of five, etc.).

Risk analysis typically involves the choice of several variables to be varied simultaneously, as project returns are generally subject to more than one source of risk. Because of the mathematical complexity involved in such calculations, the analysis of risk in this form is invariably undertaken by some kind of computer software. The process which is followed (and which is usually referred to as "Monte Carlo" or simulation analysis) is that values for individual variables are generated randomly according to their respective probability distributions, combined with other randomly-generated values for the other variables, and these figures are used to calculate an estimate of the project NPV. This process is repeated a large number of times (a number which is specified by the analyst—in effect, equivalent to implementing the project again and again in different circumstances—and is usually at least 1000 times, and typically more than this) and an average (or "expected") NPV is produced together with an associated probability distribution. This distribution can usually be viewed in the form of charts like those in Figures 1 to 3.

The early literature on risk modeling (e.g., Reutlinger 1970, Pouliquen 1970) and also standard texts on project appraisal (e.g., Little and Mirrlees 1974, Squire and Van Der Tak 1975, etc.), as well as ADB's 1985 review, all mention the fact that computer time and expertise is likely to be a major constraint to the use of this technique. In recent years this constraint has largely been overcome and more than adequate computational facilities and software are now available to practitioners.

There are even examples of risk modeling using spreadsheets alone (see Clarke and Low 1993, for example). In the model described in this particular article, a standard spreadsheet (e.g., Excel, Lotus) is used to generate random values (through the use of a built-in function—@RAND in the case of Lotus) which are then repeatedly applied to variables identified within the project "base case" scenario so as to generate a distribution of outcomes (counts of observations of variables/expected NPV values are recorded in cells so as to construct a frequency distribution). Expected NPV and IRR for the project are calculated based on the distribution of results, and the base case is then presented in terms of expected NPV/IRR, plus a range in which outcomes will lie 90% of the time (based on all variables being subject to simultaneous change). It is to be noted that the technique is quite simple and practicable, and requires no more information than is already required for traditional sensitivity testing.

Technical Issues in Modeling Risk: Two Considerations

However, despite the overcoming of computational limitations to the application of such techniques, two major practical considerations (and possibly constraints) remain as regards the extent to which such techniques as Monte Carlo simulation can be used in project preparation situations.

Firstly is the issue of data availability, and the extent to which the situation can reasonably be defined as risk (as opposed to uncertainty) through the construction of a meaningful probability distribution of outcomes. The actual situation with data availability is likely to vary enormously both between project situations and also across different sources of variability within any one project environment. At one extreme, large volumes of reliable cross-sectional or time series data may be available from historical sources for the variable concerned (e.g., for rainfall, for commodity prices, for traffic flows). At the other extreme may only be the existence of a few data points (e.g., "most likely" values, absolute minimum possible, maximum possible, etc.) which are expectations of experts/analysts involved in preparing the project. Other possibilities lying within these bounds include the forecasting / specification of power-generation theoretical capabilities adjusted for a set of likely different operating conditions, forecasts of trade flows and commodity prices (e.g., based on World Bank publications taking into account world supply and demand factors), etc. Software such as @RISK often has capabilities to fit probability distributions of different types to raw data sets supplied by the analyst. Such routines will fit distributions to data and also provide a measure of the goodness of the particular resulting fit.

It is important to note, therefore, that very large and complete data sets from empirical sources are not always necessary for the undertaking of risk analysis. Simplifying assumptions about variable distributions can be made—as a bare minimum, triangular distribution from three points (i.e., "most likely", "minimum possible", "maximum possible") can be constructed based on "best guesses" of project preparation team members. There is also often considerable expertise within the project preparation environment about the likelihood of variables or outcomes which may not be available from official sources but which can be elicited from potential project participants. Good examples of such knowledge might include rainfall and water flow, crop yields, time taken to collect water or firewood, or travel to market, operating efficiency of agroprocessing machinery, number of family days sick per year, etc. The 'Delphic' method of eliciting opinion from local experts is an example of this type of approach, and has been applied (in a probability-based form) by, for example, World Bank in a risk analysis of institutional reform in the irrigation sector in Pakistan (Dinal et al. 1997).

Well-tried empirical methods exist for developing probability distributions from such subjective sources. These include

- visual impact techniques (e.g., matches or stones piled up to represent frequency of value occurrence),
- structured questions to identify key points in a distribution (e.g., the median, quartiles, etc. – the "judgmental fractile" method), and
- the application of "smoothing" techniques in situations where a few real data points may be available.

Some proponents of probability-based risk analysis (e.g., Clarke and Low 1993) also argue that the shapes of particular distributions of individual variables (e.g., choosing between uniform, normal, triangular distributions for variables such as crop yields, traffic flow, enrolment rates, income differentials, etc.) are less important than the choice of variables themselves which are allowed to be modeled. In the Clarke and Low example (from an agricultural project in East Africa), the random number generation approach necessarily produces a rectangular uniform distribution (i.e., one in which all possible observations within the range defined by the analyst have equal probability of occurrence), although with more complex formulae being written this could be adjusted. Recent experience of preparation of power projects within ADB also suggests that the particular form of distributions also matters less if a large number of simulations are run. Even when considerable effort is made, for example, to replace the quoted discrete distributions with relatively few values by continuous distributions based on large amounts of empirical data, there is little difference in resulting distributions of EIRR/ENPV outcomes (i.e., expected values and variance, minimum and maximum values, etc).

However, this approach may not always be appropriate for all variables, and it still requires judgment on the part of the analyst about what ranges are acceptable for values to fall within. Also, to adjust the spreadsheet model to produce (for example) a normal distribution (as opposed to a uniform one) becomes very much more complex.

It is also noted in the early risk literature (e.g., Pouliquen 1970) that there is no a priori case for the use of normal distributions (even as a default distribution), as all variables are not always subject to relatively large numbers of random influences (which is what typically causes a variable to be normally distributed).

Overall, therefore, the techniques applied to develop definitions and derivations of probability distributions for individual variables in most cases is likely to depend upon some subjective judgment by an appraisal team — and inevitably the extent to which these design assumptions adequately reflect the reality of the project will vary from case to case. The suspicion that what appears as a full-scale risk analysis has in reality only a spurious precision can be ultimately only fully allayed if the data upon which the variables' probability distributions are constructed (either from historical evidence, future computational forecasts, or analysts' 'best guesses') are believable.

The second consideration when applying risk analysis in practice is the extent of covariance between those variables that are to be selected for risk analysis. Projects are rarely subject to only one source of risk, and therefore more than one variable at a time is modeled in the Monte Carlo simulation exercise. However, statistical complexities can arise depending upon the relationships between the selected variables. Where variables are in fact statistically independent of one another there is no problem, as it is appropriate to treat them independently. Where variables may be thought to be related in some way, however, the extent of covariance between them needs to be taken account of when specifying the distribution of individual variables in some type of simulation (again, typical risk analysis software such as @RISK can handle this within the context of specifying correlation matrices).

As an example, project revenues are typically products of both quantities sold and prices obtained. If these underlying variables are correlated in some way (which may well be if project output is large relative to market volume, and negatively so in this case) the expected value of the product of two random variables (i.e., project revenue) is equal to the product of the individual expected values plus the covariance between the two variables. Another typical example of covariance (which would be positive in this case, if it is assumed to be due to improved, project-induced water supply under an irrigation scheme improvement) may be that between area planted and average yield (i.e., with both variables as determinants of farm production volumes). One of the case studies using @RISK includes correlation between estimates of proportions of trainees finding employment, and the numbers of days and months of employment gained following nonformal training in Bangladesh. In practice, the approach to assigning particular levels of covariance between variables is quite pragmatic, and typically simple rank correlation coefficients between pairs of variables are sufficient for most purposes (in the risk software packages, correlation between variables—once specified—can typically be "toggled" on/off).

It is specifically recommended that disaggregation of individual variables be limited as much as possible so as to avoid including too much correlation in the analysis. For example, although individual construction cost items (e.g., cement, cost of floor, cost of walls) may each be thought to vary individually, in reality the sources of this variability all arise from one point (e.g., costs of imported cement), and this could be most appropriately captured through some item such as "construction materials" rather than by introducing additional correlation between such items (which would tend to increase unnecessarily the estimate of overall variability). Akin to the nature of some subjective judgment being involved in the allocation of probability distributions, there is therefore a similar judgment to be made about the extent of disaggregation to be applied in individual circumstances.

In sum, the principles to be applied in practical situations to quantitative risk analysis such that the issues just described are dealt with as transparently as possible are summarized in the following table:

Table 2

Principles to Apply in Data Handling for Probabilistic Risk Analysis

	Principles to Apply
1	Identify those variables for which future values are unknown and which are likely to affect project returns (i.e., the 'key' variables)
2	Fully explain the general nature of the data set which is used for modeling those variables' values (its origin—i.e., from objective or subjective sources, whether it is based on historical observations or forecasted projections, the number of observations the data set contains, its extent of completeness/any missing data points, etc.)
3	If the data derives from subjective sources, explain the method by which it was elicited (e.g., from visual techniques, from subjective questioning, from an expert-based 'Delphic' process, etc.)
4	Explain the statistical nature of those variables' assigned probability distributions (i.e., whether these distributions are triangular, uniform, normal, logarithmic, exponential, etc.)
5	Make clear the goodness of fit of the distribution to the data set (if one has been fitted using @RISK or similar software), and quote appropriate statistical measures (e.g., Chi-square, Kolmogorov-Smirnov, Anderson-Darling statistics, etc.)
6	Make explicit any correlation thought to exist between variables used in the risk analysis (i.e., its extent, and the technical, real-world basis for the assumption, etc.), and (based on this)
7	Explain and justify the extent of any variable disaggregation.

The focus of the reporting of the results of risk analysis will be the likelihood that project returns may be negative (e.g., "the project's rate of return is likely to be unacceptable in about 15% of all cases"), but such reporting should not obscure any basic qualifications about the analysis which need also to be included, and especially about the extent of correlation which has been assumed. "Good practice" in this regard is likely to require reporting "with" and "without" correlation being applied in the simulation as the effects of ignoring correlation can be substantial.

Risk Analysis, Decision-Making, and Welfare

The result of risk analysis as just described is therefore to identify projects (or alternative designs of the same project) which now have two essential characteristics—i.e., the expected value of their economic return (as measured by their expected ENPV, EIRR, etc.) and their degree of risk (as measured by their variability in general—captured by the distribution's measures of dispersion, such as variance and coefficient of variation, and also by the probability of the return falling below some unacceptable level in particular). This quantitative measure of risk adds to the information available to the decision-maker, although in itself does not necessarily provide any guide as to whether any individual project is acceptable (or even as to which project among several possible ones actually should be undertaken).

The discussion of the 'acceptability' of particular levels of risk is usually presented in standard economics texts in terms of choice among competing projects. Consider the following three project alternatives (A, B, and C) as shown in Figure 4.

In Figure 4, project B is clearly "inefficient", in the sense that its variability is the same as project A, but its expected value is lower. Project C has a higher expected NPV than project A but it also has a greater variability of returns (including the possibility that its return will be zero). If variance of returns is plotted against expected values for such project situations as A, B, and C, the following is obtained (Figure 5 - in what is usually referred to as E-V space). Projects A and C may lie on the efficient investment frontier—although at different points, while project B lies within the inefficient frontier.

In this case, the expected higher returns of project C have to be weighted against the increased degree of risk of the project. How should a decision be made between the alternative projects? The traditional view taken towards public sector investment was that governments with large project portfolios could afford to ignore the riskiness of investments as long as the expected values were acceptable—i.e.,

Figure 4

Probability Distribution: Three Projects

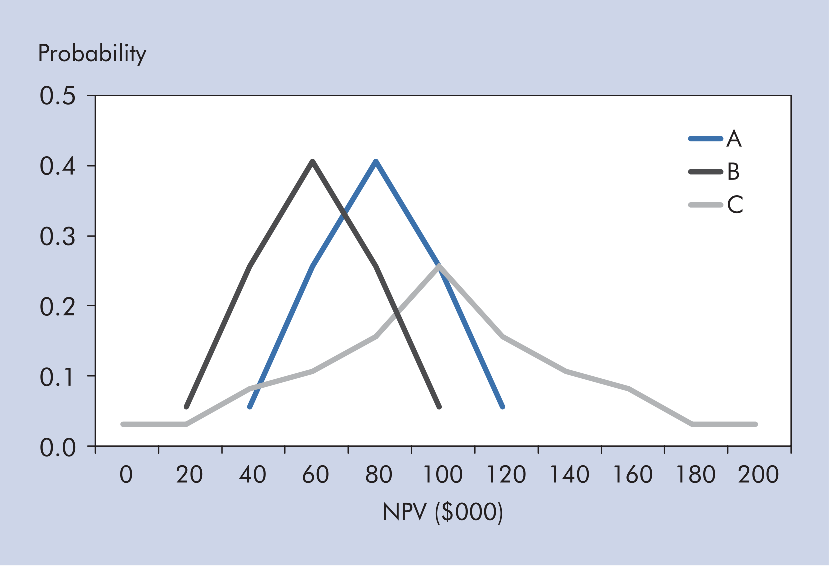
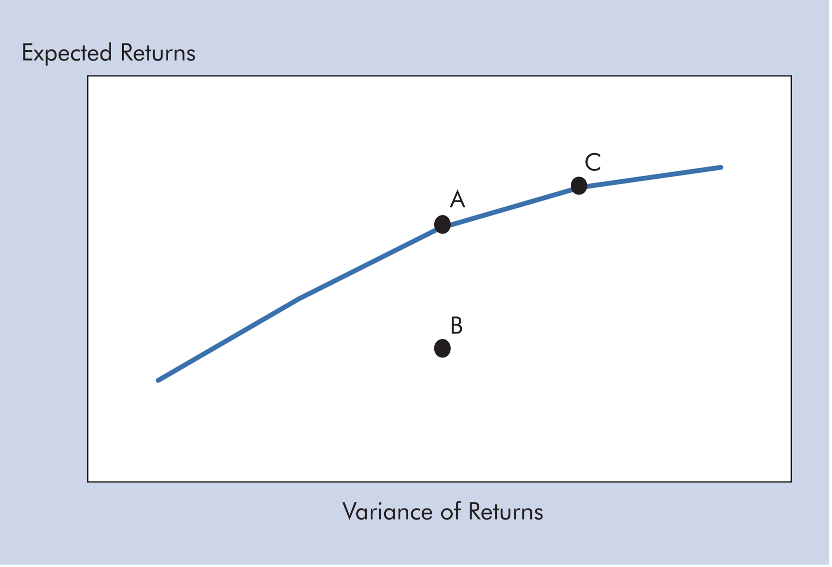


Figure 5

Expected Returns-Variance Frontier

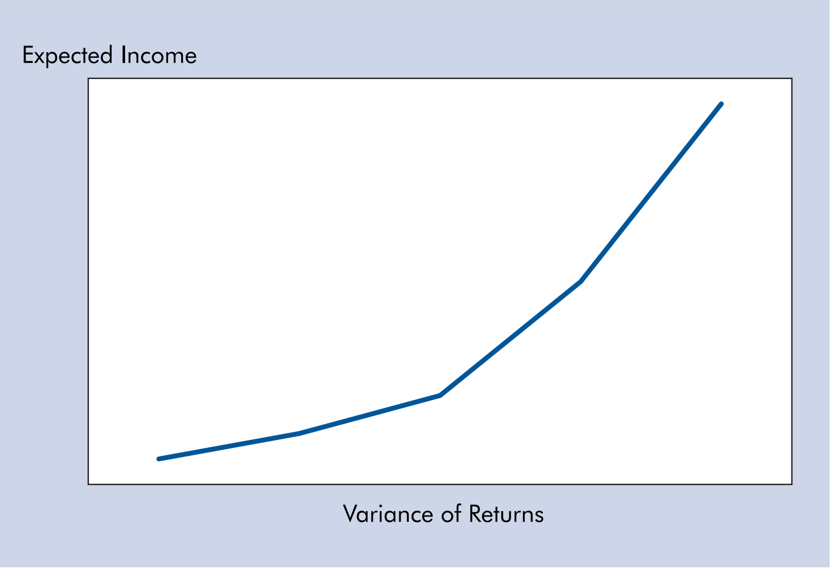


they could afford to be "risk-neutral". This is because, with a large number of investments spread across all of society, the costs of any individual project failures could be absorbed within the portfolio as a whole. Exceptions to this view were projects which were either very large, or were somehow correlated with national circumstances (such that good performance of the project in bad years for the economy as a whole was worth more in terms of a disproportionate contribution to national income), or affected particular groups (e.g., in one region, one type of student, etc.) such that the impact on those particular individuals could not be ignored.

In fact, there is no answer to the question of project choice in such circumstances without reference to knowledge about the extent of decision-makers' risk-aversion (i.e., the rate at which they are prepared to trade-off levels of expected returns—or in effect, income—against levels of variability of returns). Figure 6 shows how many individuals are thought to be risk averse; the line joins points of equal utility (i.e., welfare or satisfaction – and is in fact an indifference curve) from combinations of expected income (measured, say, in $000) and variability of income (measured by annual income variance). What it suggests, in general, is that for people to accept greater variability in their incomes they need to receive increasingly larger expected incomes.

Figure 6

Risk Aversion: Line of Equal Utility



The actual nature of decision-makers' utility functions as regards their risk aversion occupied a large literature (much of it deriving from agricultural economics and work with small farmers in developing countries) around the same time as the classic texts on project appraisal and risk analysis were written, where it was hoped that insights about preferences regarding risk would lead to making optimal project choices. The results of many classic empirical studies of risk perceptions from the 1970s (e.g., Anderson 1974, Swalm 1966, etc.) suggested that most individuals were risk averse, although the specific income levels at which this was the case and also the extent of risk aversion could vary enormously even within apparently similar circumstances (small farmers in Africa, Australia, and the USA, workers in large corporations, professionals and business executives were all studied).

In order to fully understand how people actually deal with risk in project and other situations in terms of the decisions they make, academic risk literature has also concentrated on the extent to which

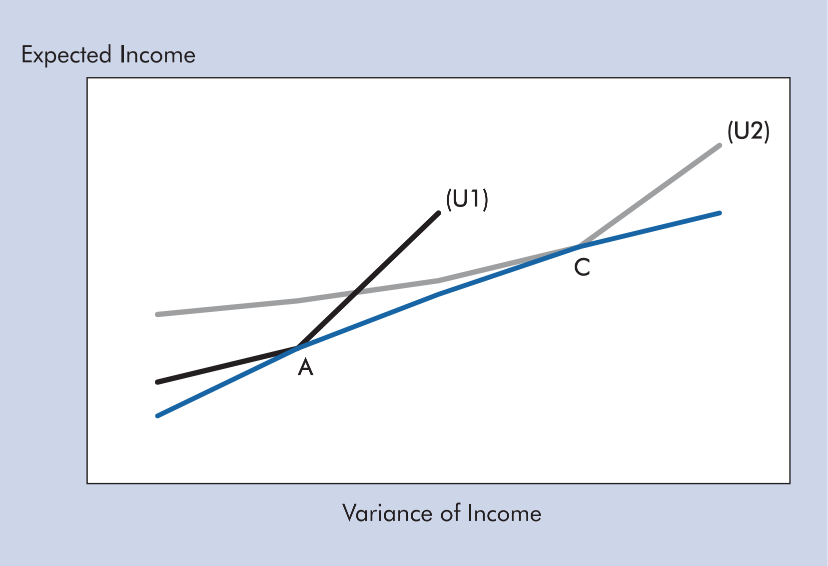
- the consequences of particular risks are catastrophic or not,
- the risks are controllable at the micro level or not,
- the consequences are reversible or not, and
- the risks are insurable or not.

These considerations are returned to in Part IV in relation to the attitudes of the poor.

To complete the above analysis and understand what decision actually *should be* taken in any particular circumstance, it is necessary to combine the notions of efficient projects located in E-V space with decision-maker's utility functions expressed in the same space. Thus in Figure 7 below, one decision-maker on the basis of an individual utility function (U1) will choose project A (lower expected NPV, lower risk) while another will choose project C (higher expected return, higher risk) on the basis of a utility function such as (U2).

As well as the E-V approach to considering the risk-reward relationship, other models have attempted to capture the characteristics of this situation within the context of financial investment portfolio analysis. Probably the most well-known of these approaches is the Capital Asset Pricing Model (CAPM, developed by Sharpe and Lintner in the 1980s) which measures an individual stock (or project) risk relative to the volatility of returns relative to a market (or sector) index. Again, however, ADB practice as regards project economic and financial analysis is not primarily concerned with a number of projects as they may comprise an investment portfolio (or even with one project within the context of all projects in the portfolio), but with analyzing risk as faced by individual projects one at a time.

Figure 7
Project Choice and Risk Aversion



Summary of Approaches to Risk Analysis

This Part of the Handbook has summarized approaches to dealing with unknown outcomes in project analysis through description of various techniques attempting to capture the content and consequences of uncertainty and risk. It is clear that the quantitative modeling of risk is in principle preferable to the simple depiction of uncertainty, although it is also obvious that data and time considerations (and the difficulties in properly identifying and specifying covariance among variables) have often limited the extent of actual risk analysis practice. However, it is also the case that the present availability of computer software to easily process Monte Carlo-type simulations from data already available to the analyst within spreadsheets, plus the existence of statistical routines and computational processes to fit probability distributions to many (even quite sparse) data sets, greatly increase the possibilities for application of quantitative risk analysis as a more commonplace part of project design.

The results of quantitative risk analysis can greatly inform the process of project design, so that mitigation measures can be put in place before projects are implemented. They can also increase the information available to decision-makers about individual projects (i.e., so that their likelihood of failure is identified). While the results of risk analysis are quite easy to understand in conceptual terms for planners and project staff, however, these results in themselves do little to aid project investment decision-making unless and until they are combined with some consideration of planners/policymakers and/or project participants' risk aversion. What level of risk is it appropriate

- for ADB to accept?
- for ADB to suggest that borrowing DMC governments or institutions accept?
- to impose upon groups of project beneficiaries?

are questions which have to be answered outside the scope of those quantitative techniques which provide the measures of project risk. The question is akin to the difficulty of suggesting *a priori* cut-off points for the Poverty Impact Ratio (PIR) as it is inherently associated with social welfare functions as perceived by decision-makers.

Following a review of agency experience with the application of the techniques just outlined (in Part III), it will be suggested (in Parts IV and V) that strengthening risk analysis in ADB operations involves both greater application of the probability-based techniques for modeling sources of risk in project design (located within a framework to guide such application) and also greater awareness of attitude towards risk amongst those being planned for in ADB projects.

3

A Summary of Development Agency Experience in Applying Risk Analysis

Introduction

This Part of the Handbook reviews ADB's and other agencies' actual experience with risk analysis in recent years.

The review of ADB experience is based on a review of some 50 recent RRPs covering projects in all sectors of lending operations to identify what risk analysis practices have been employed by ADB in practice (see list in Appendix 1). In addition, various project performance appraisal reports, impact evaluation studies (covering the late 1980s and 1990s), special studies, and sector syntheses (from 1994 to 2000) were reviewed to find out to what extent those variables which were thought to have affected project impact during implementation were in fact those which had been identified as sources of risk or uncertainty at the time of project preparation and (if they had been so identified) to what extent any attempts had been made to model them as "risky".

The experience of the World Bank is also considered in this regard, and a number of projects were briefly reviewed which are propounded (e.g., in Belli et al. 2001) as examples of "good practice" of risk analysis. It will be seen that the actual practice of risk analysis falls somewhat short of what may appear to be advocated in its official publications.

The experience of some other agencies with approaches to risk analysis is also considered, notably that of the UK's Department for International Development (DFID 2001) and also the UK Treasury (2000). DFID's experience is notable for the purpose of the current study because that agency previously adopted a quite traditional approach to project economic analysis (including its technical approaches to risk analysis) but has now (along with most bilateral development agencies) shifted its analytical focus away from quantitative cost-benefit techniques and towards a more participant-centered and "pro-poor" driven "livelihoods" approach (within the context of pursuing poverty reduction as its overall objective). However, within this "livelihoods" framework (which is also increasingly being favored by World Bank) the need to assess vulnerability of target groups has actually increased the attention devoted to risk assessment, although not in a quantitative sense. DFID's experience and practice is also noted for the rigor of the application of the logical framework technique and the explicit attention to identification of sources of risk within this framework.

Actual experience with the use of risk analysis by major agencies is then considered within the context of a recent critique of project economic analysis by Harberger (1998). It is suggested, *inter alia*, that various biases are routinely introduced into estimation of project costs and benefits, and that among the ways of dealing with such unknowns greater attention should be paid to risk analysis (through the application of simplified simulation techniques).

ADB Experience With Risk Analysis

With the notable exception of a port project, an agriculture project, and the few power sector projects described below, ADB's experience with quantitative risk analysis has been very limited, although the existence of risk as affecting project outcomes is indeed very well-recognized. A review of some recent RRPs, and which cover all sectors of ADB project and policy lending operations, suggest the following main points:

- the standard format of an RRP invariably includes a section (usually within the 'Financial and Economic Analysis', but sometimes presented separately and called variously 'Risks', 'Risks and Safeguards', 'Risks and Assurances', etc.) describing qualitatively the risks which a project is expected to face
- this text usually (but not always) includes descriptions of the measures which have already been incorporated to mitigate such risks. Typical risk-mitigation measures include the provision of technical assistance to strengthen institutions, the provision of counterpart funding, and also the inclusion of a number of different components being included within the project ambit. Sometimes such identified risks are called 'micro' or 'project' risks (i.e., they are risks over which the project has some control), and are distinguished from 'macro' or 'sector' risks (over which the project has no, or very limited, control but which are not regarded as being significant enough to jeopardize project success)
- this is often followed by a section called 'Assurances' which contains statements/letters to ADB from the borrower regarding operations during project implementation, often designed to formalize and support the proposed mitigating measures which have been agreed upon
- Appendix 1 of the RRP is invariably the 'Project Framework', which identifies and summarizes the risks as previously discussed, and places them in the context of the project's hierarchy of objectives. There is no separate discussion here of risks' likelihood and seriousness, however
- the 'Financial and Economic Analysis' section of an RRP often argues that 'conservative' or 'pessimistic' estimates have been used for forecasts of (for example) shipping, road and rail traffic volumes, crop prices, yields and production, fisheries catches, etc., upon which benefits have been estimated
- in addition, often the fact that certain benefits are identified but not quantified and valued in EIRR calculations is used to argue that the 'base case' EIRR is 'conservative' or 'understates' real returns. There is thus a 'cushion' which supports the likely acceptability of project returns
- the 'Financial and Economic Analysis' section usually contains a fairly standardized approach to sensitivity testing, in which project aggregate 'base case' costs and benefits streams are changed by 10% or 20% each

and benefits are delayed by one or two years, and the effects of these on the project 'base case' EIRR are considered (both in isolation and in combination with one another). Some studies are now more detailed, and calculate switching values and sensitivity indicators

- the project is then usually described in terms of its 'robustness', i.e., in the 'worst case' scenario (when cost changes are highest, benefits most reduced and/or delayed, etc.) its EIRR is still above 12%; sometimes, the statement is (improbably) made that, given its ability to survive such adverse circumstances, 'the project faces no risk'.

This format is remarkably similar across projects in all sectors. In the case of program loans, qualitative discussions of risk are included in the text, and the policy matrix will usually contain a column describing 'actions planned', many of which deal with management of identified risks.

ADB practice recognizes that risks exist at different levels of objectives achievement. It also tends to closely link identified specific risks with those mitigating measures which are already included in project or program design. Moreover, it routinely exploits sensitivity testing to demonstrate 'robustness'. While ADB's practice could be argued to be very strong, it could not be said to incorporate quantitative risk analysis practice in any form.

The apparent exceptions to this conclusion are the Bintulu port project, an agriculture project, and several very recent power projects. The Bintulu port project was cited and extensively described in Johnson (1985). The analysis of this project involved the estimation of probability distributions of several types (triangular, trapezoidal, uniform) for different elements of the costs and benefits streams and the construction of a probability distribution of the EIRR based on 300 samplings/replications. The output of the analysis is described in terms of the probability of the EIRR being more than acceptable (i.e., in excess of 12%) in 97% of samplings. What is perhaps interesting to ask, is why such a probability-based analysis was undertaken in 1979 (when presumably access to computational resources was far more restricted than is the case in recent years) for a ports project and yet was not for later similar ports projects (e.g., the Xiamen Port Project in 1997, the Belawan, Banjarmasin and Balikpapan Project, also in 1997). In both these later cases, references to 'conservative' traffic forecasts are combined with extensive sensitivity testing as ways of dealing with unknown future values.

Recent preparation of power projects in ADB have systematically employed risk analysis, and, interestingly, this has been very much along the lines suggested by Harberger's 1998 argument and in a similar fashion to the World Bank Mexican irrigation and power project examples (see below). In the cases of two ADB power projects[1] for example, discrete probability distributions containing between three and five possible values (based on PPTA mission estimates) for five to six variables in each case (covering capital and other cost elements, commissioning delays, willingness-to-pay (WTP) estimates, foreign exchange, as well as aggregate financial costs and benefits) were used to run a Monte Carlo simulation which generated expected values for project EIRR, together with estimates of standard deviation (i.e., the square root of variance), minimum and maximum values. A cumulative distribution function was also plotted in each case, indicating the probability of negative or less than acceptable (i.e., below 10-12%) economic rates of return. Each simulation was run 3,000 times using "Risk Master" software. The models also incorporated estimations of correlation between variables. In addition, the most recently-prepared of these projects (the Shen Da project) included a risk analysis following on from the calculation of the PIR, and a cumulative distribution function (CDF) was estimated for the PIR itself (see discussion in Part IV of the utility of this exercise).

This approach to risk analysis is certainly pioneering within ADB at present (and in fact relies upon the use of a personal, rather than institutional, copy of '"Risk Master" software). It is suggested by staff working in the power sector that it has been very useful during project design (typically at the fact-finding stage rather than at PPTA) to investigate concerns connected with one or two 'key variables' (typically elements of input or output prices). The main effort in terms of additional work lies in selecting key variables, ensuring there is no correlation between them (or that its extent is fully understood), and designing a 'best guess' distribution for each variable. With familiarity of the sector and/or local conditions this exercise may be completed over the course of a few days, and running a simulation based on several thousand samplings will take only a few hours. The result is certainly a presentational improvement, and usually argued to be an increase in 'peace of mind' regarding project robustness.

Another exception concerns the Infrastructure for Rural Productivity Enhancement Sector project in the Philippines which used the @Risk software to simulate the impact of changes in the values of key variables on the feasibility of proposed investments in rural roads and irrigation development. The analysis applied triangular distributions constructed around the mean for key variables, whose upper and lower values were apparently based on subjective estimates of project designers. The results of the analysis presented features of a distribution of the expected values for the EIRRs of each of two project components (i.e., rural roads, irrigation), but did not present the probability of the overall EIRR being less than the opportunity cost of capital.

---

[1] People's Republic of China's Windpower Development Project, and People's Republic of China's Shen Da Power Transmission and Grid Rehabilitation Project.

Given that the estimation of risk in this way relies only upon a few estimates of likely values of several key variables and also some estimate of correlation among those variables, there would seem little reason as to why its use should be restricted mainly to ADB power projects. Power projects may be typically relatively large investments, but they are not necessarily more prone to risk from exogenous or endogenous sources than (for example) transport or irrigation projects, and technical staff involved in preparing such projects are likely to have just as much basis (deriving from both historical data and informed projections of the future) for estimation of probable outcomes as do ADB energy staff.

Indeed, a review of ADB project performance across all sectors (based on sector synthesis reports) suggests that many events occur to project environments during implementation which are responsible for divergences between estimated economic outcomes (i.e., EIRR, ENPV) as anticipated at appraisal and those estimated at post-evaluation and which in fact could have been subject to risk analysis at the time of project preparation. Table 3 summarizes (by sector) what were the main technical factors causing differences between anticipated and actual outcomes. What is immediately clear is that most of the factors which have been so identified could have been subjected to some form of risk analysis, and perhaps better project (re-) design may have resulted if risk analysis techniques had been applied.

What also emerges from the table is that other factors which cause differences in economic returns as estimated prior to and post-project implementation (typically depending upon how benefits—especially environmental ones or those based on willingness-to-pay – have been approached) could have been subject to greater variation quantification as well. Overall, the evidence suggests that there is a strong prima facie case for more rigorous risk analysis in ADB project economic analysis.

Adding to such findings, a ‘Special Evaluation Study’ (1998) of factors affecting project performance in agriculture and social projects between 1991 and 1997 suggested that ‘greater realism’ was required at PPTA stage in estimating project costs and benefits so as not to consistently over-estimate EIRRs, and that particular attention should be paid to dealing with aspects of local government performance in project preparation. Again, these considerations could at least in part be tackled through greater application of risk analysis. Similarly, the special evaluation study on involuntary resettlement (2000) concluded that social investigations at the PPTA stage had often been weak and/or hurried in preparation, and that greater attention to project participants’ risks (e.g., of impoverishment) was warranted.

In addition to sector-based work, a 1997 special study of the macroeconomic environment and project performance (across all sectors and from 1980 to 1997) in Sri Lanka found that numerous variables such as world market prices, the nominal exchange rate, scale of duties and tariffs, shipping costs, various government controls,

Table 3

Sources of Differences Between Estimates of Economic Benefits, Pre- and Post-Implementation, by Sector

OED Sector Synthesis	Factors Affecting Estimates of Economic Outcomes	Comments
Irrigation and rural development	Cost overruns; implementation delays; untested technologies; cropping intensities; poor water management	All conceptually subject to risk analysis
Rural and agricultural credit	Repayment rates; debt amnesties; rates of interest; government commitment	Many (if not most) conceptually subject to risk analysis
Fisheries	Price trends; numbers of vessels; fish stock composition	All conceptually subject to risk analysis
Forestry	Benefit estimations and valuations	Difficulties in estimating non-direct use values; could have been approached using sensitivity analysis, and/or "with or without" inclusion, and perhaps risk analysis
Industrial crops	Yields and prices; cost overruns; mills capacity and throughput	All conceptually subject to risk analysis
Health and education	Institutional performance; health, morbidity and mortality levels; cost of services (participation rates and demand)	Many conceptually subject to risk analysis
Urban development and housing	Land values; benefit valuation methods	Some conceptually subject to risk analysis, and land valuation could have been approached using sensitivity analysis, and/or "with or without" inclusion, and perhaps risk analysis
Water supply and sanitation	Cost overruns; WTP estimation	Some conceptually subject to risk analysis; WTP estimates could have been approached using sensitivity analysis, and/or "with or without" inclusion, and perhaps risk analysis
Power	Cost overruns; capacity and generation/transmission losses; WTP/resource cost savings estimates	All conceptually subject to risk analysis
Roads and transport	Implementation delays; cost overruns; traffic flows; vehicle operating cost (VOC) savings	All conceptually subject to risk analysis
Ports and shipping	Implementation delays; cost overruns; traffic volumes; benefit estimation methodologies	All conceptually subject to risk analysis

etc. had all affected project outcomes. An explicit conclusion of the study was that greater attention to analysis of these variables at project design might have improved project effectiveness. An implicit conclusion may also be that quantitative and/or qualitative risk analysis techniques could have been employed to consider such variables more carefully.

World Bank Experience With Risk Analysis

The World Bank devotes relatively more of its basic publication on project economic analysis (Belli et al. 2001) to the analysis of risk than does ADB in its comparable documentation (i.e., ADB 1997a). In this publication, a discussion of sensitivity analysis and its shortcomings is followed by a presentation of the principles of calculations based on mean-based expected values and the use of Monte Carlo simulation (including a hypothetical example). The problems of developing probability distributions for variables are discussed, and there is some description of judgmental methods applied to derive distributions in the absence of complete data sets. There is also a discussion of the implications for decision-making of risk analysis, concluding that (risk analysis is perhaps of limited use in decision-making terms due to governments' supposed risk-neutrality) the techniques are more likely to be of use in the processes of project design and redesign, rather than in decision-making per se.

Overall, the presentation of the material is relatively thorough, if somewhat traditional —being oriented mainly around the use of Monte Carlo techniques, and specifically recognizes the fact that the kind of analysis and presentation of issues associated with risk which are advocated are "extremely rare in existing documents". World Bank accepts that in situations when projects are large with respect to a particular region or group of people the ENPV criterion alone (i.e., without any associated measure of risk) is an inadequate measure of investment acceptability—but does not pursue the consequences of this thinking towards (for example) pro-poor project lending.

Two projects with risk analysis are given as examples of somewhat different types of "good practice". The first, from an irrigation project in Mexico, identifies three sources of risk (inadequate government counterpart funding, delays in surveys and studies, and unwillingness to invest/ problems with access to credit) which (collectively) have two sorts of impacts—implementation delays and low adoption rates. These two impacts are each then divided into three scenarios ("optimistic", "modal", "pessimistic" in the case of adoption rates, and delays of 0, 1, and 2 years in the case of implementation) with estimated probabilities of occurrence (0.1, 0.5, 0.4, 0.35, 0.4, 0.25, respectively), and EIRRs calculated for the resulting nine (i.e., 3*3) possible different scenarios. The result of this approach is a table of events (i.e., combinations of adoption rates and delays) with their associated probabilities and EIRRs. It is shown that even under the most pessimistic of assumptions (in this example this results from pessimistic adoption rates and a 2-year delay in implementation), which has a probability of occurrence of 0.1 (calculated from the multiplication of the likelihood of 0.25*0.4) the calculated EIRR (of 12.7%) is still in excess of the opportunity cost of capital (assumed to be 12%). A cumulative distribution function for the range of EIRRs is shown in tabular form, and could have been presented graphically as well.

This sort of approach is very similar to that advocated by Harberger (1998), which is discussed below. It is simple, clear and can be undertaken with only very limited suppositions about the probability of certain states occurring. Arithmetic calculations are trivial, project designers' or participants' ability to identify a few possible states for individual variables is likely to be plausible, and the resulting combinations of possible states is quite likely to be representative of the range of situations.

The other quoted example ("the most transparent and complete economic and risk analysis") is from a technical and higher education project in Mauritius (prepared in 1995). This project was clearly innovative from the World Bank's point of view as regards its economic analysis, and appears to be the first World Bank education project for which a measure of net worth (as opposed to a cost-effectiveness approach) was used.

In the project's economic analysis as presented in Belli et al. (2001), three variables which affect returns (income differentials between graduates and non-graduates, employment rates of graduates, enrolment rates) were identified, and each assigned probability distributions (log-normal, and two different triangular forms, respectively). A resulting probability distribution of project benefits is shown in graphical form. In the actual Staff Appraisal Report (SAR—and available on *www.worldbank.org*) for the same project, different variables appear to have been analyzed (major cost and benefit items) using different sorts of distributions—truncated and non-truncated normal distributions and one uniform distribution. A full Monte Carlo simulation—using 3000 replications, with and without correlation assumed between different variables—was ran at appraisal, and a probability distribution of net benefits was produced.

When considering this particular project material and the general nature of this type of approach (in contrast to the Mexico irrigation project, for example), it should perhaps be noted that the risk analysis as described in project documentation involves considerable technical discussion of the nature of variables' distributions, and the appropriateness of the particular techniques applied. It is also the case that the risk analysis of the Mauritius project itself apparently took four weeks of staff time (on the part of one summer intern, presumably with a strong statistics background) to complete.

Other, arguably much more typical, examples of risk analysis from World Bank practice include (firstly) the $350 million Ghazi Barotha Hydropower Project in Pakistan (SAR, 1995), where least-cost and economic net worth analysis was conducted, and then a sensitivity analysis (for delays and cost overruns) was supplemented by a risk analysis of the type used in the Mexico irrigation example, i.e., four factors affecting project returns were modeled as having three possible states each, and EIRRs were calculated for each. (This process was undertaken for the project in the context of the power sector as a whole and for its own stand-alone operations). As for the Mexican example, a cumulative probability distribution of outcomes was constructed, so that it could be said (for example) that "the probability of the project's rate of return being less than the opportunity cost of capital is 8 percent." Another project example is the Xiaolangdi Multipurpose Project (Stage II) in China (SAR, 1995)—a $430 million loan, where probabilities of river flow volumes are discussed, although only appear to be modeled in terms of sensitivity analysis.

Other examples of World Bank practice in dealing with risk in various ways include the projects shown in the following table. What is clearly similar to the experience within ADB is that it is projects in the power sector which are analyzed most fully in quantitative risk terms.

Other Agency Experience With Risk Analysis

A scrutiny of recent literature published by bilateral agencies such as Danish International Development Assistance (DANIDA), Danish Cooperation on Environment and Development (DANCED), AUSAid (Australian), GTZ (German), and FINNIDA (Finland) regarding preparation of project or sector loans reveals very little about general guidelines for economic analysis (in the sense of quantitative cost-benefit techniques), or risk analysis in particular. One reason for this is obviously that such agencies are (by and large) disbursing grant or extremely soft funds, often in relatively small amounts and do not have the same fiduciary accountability requirements as a bank such as ADB. It is also the case that operations by such agencies are increasingly in sectors where monetized costs and benefits are less obvious than historically may have been the case.

The prevailing view among bilateral grant-based aid agencies, as reflected in the available documented techniques for project preparation is that projects are assessed primarily in qualitative terms, with a focus on institutional and sustainability issues, rather than on estimation of economic returns per se. Exceptions (and

Table 4
Examples of Risk Analysis from Recent World Bank Projects

Project Title and Date	Features of Risk Analysis
Arun III Hydroelectric Project (India, 1994)	Four factors affecting performance, with 2 or 3 states each, were used to generate probability distribution of EIRR; 'sensitivity testing' of basic assumed probabilities was also undertaken for several variables
Waigaoqiao Thermal Power Project (China, 1997)	5 'risk variables' with 5–6 states each used to generate table describing expected EIRR with standard deviation, minimum/ maximum values, probability of negative outcomes, etc. (uses 1000 simulations in Risk Master software)
National Drainage Program Project (Pakistan, 1997)	Includes quantitative assessment of political-economy risk regarding implementation and impact of various reforms, but not measured probabilistically in terms of EIRR distribution
Third Andhra Pradesh Irrigation Project India, 1997)	Combinations of variables' values used to estimate range of EIRRs; 'risk analysis' is really extended sensitivity testing
Yunnan Environment Project (China, 1996)	Wide range of technical, financial, institutional and policy risks, classified as short-term/medium and long-term/strategic; these are described qualitatively, and presented in matrix format with identified mitigating measures and parties responsible
Shandong Environment Project (China, 1997)	Wide range of technical, financial, institutional and policy risks, classified as short-term/medium and long-term/strategic; these are described qualitatively, and presented in matrix format with identified mitigating measures and parties responsible

sometimes, additions) to this approach are circumstances where there may be financial impacts at individual or household levels, and then crop (or farm, household, enterprise, etc.) budgets may be modeled. In these situations it appears that some kinds of sensitivity testing (e.g., yields and prices up or down 20%, etc.) may be undertaken, but not quantitative risk analysis.

One agency which used to undertake comprehensive cost-benefit or (cost-effectiveness) analysis of most of its projects is the UK DFID (formerly ODA). Its publication *Project Appraisal of Projects In Developing Countries: A Guide for Economists* (various editions 1988–1995) was a standard source text for technicians. However, while sensitivity testing is described at some length in this publication, the agency's view was that

> "risk analysis (in the sense of probability-based techniques) is unlikely to be used often for economic appraisal except in the largest projects" (page 77, 1992 edition)

and its emphasis even in such circumstances seems to have been on the capital and financial aspects of dealing with risk. While some examples of the application of the techniques of risk analysis within DFID/ODA may be found, it certainly was a far from routinely-advocated practice. An unpublished technical paper prepared within DFID in 1995 reviewed the status of risk analysis, and advocated greater use of tools such as probability/impact matrices (see below), decision trees, and histograms to guide investment decision-making. This perhaps represents the last phase of thinking about quantitative cost-benefit techniques within the agency, as this work was abandoned in view of changed priorities.

There are nowadays two major aspects of DFID's approach to project preparation techniques that have direct bearing on the analysis of risk, although not in quantitative terms. Firstly, in recent years DFID (like ADB) has taken a very strong anti-poverty focus in its operations, and this has had major consequences for its approach to project appraisal. Since the publication of the 1997 "White Paper" on poverty, DFID's approach has been far less oriented around the formal techniques of cost-benefit analysis than previously, and more located within its "sustainable livelihoods" approach (see figure in Appendix 2). One aspect of the "livelihoods" approach to promoting sustainable development is that it involves explicit assessment of households' vulnerability to trends (e.g., in crop prices), shocks (e.g., natural disasters) and cultural factors (e.g., ethnicity). This is effectively equivalent to raising the profile of incorporation of risk in project preparation work by putting it at the heart of strategic thinking, compared to previous practice, where consideration of uncertainty and risk in DFID/ODA practice was essentially seen as supplementary aspects of a quantitative cost-benefit analysis.

Secondly, within the context of the application of the logical framework technique, DFID is very rigorous in

- identifying risks (right-hand column of the DFID format, and similar but not identical to that of ADB's "Project Framework") and specifying how they relate to relationships between different levels of the framework (i.e., "output-to-purpose", "purpose-to-goal")
- clearly specifying what mitigating measures have been already within project design to address or minimize these risks, and
- compiling a "risk matrix" which locates each identified risk within a matrix whose dimensions are "probability of occurrence" and "seriousness of impact" (i.e., if the event does occur).

DFID is also notable for the preparation of a “risk annex” in its supporting project documentation, which gives it a similar status to that of social appraisal, technical appraisal, economic and financial appraisal, etc. The risk annex and risk matrix are essentially used in a qualitative way to both promote dialogue between host governments and executing agencies and to ensure that appropriate mitigating measures are put in place.

The following is an example of a DFID risk (or impact/probability) matrix from a recent project in China (Yunnan Environmental Development Programme, 2000). The numbers 1-10 refer to the 10 different sources of risk to the project, which were identified during preparation and discussed within the project’s logical framework. The identified risks comprised the following

Risk 1: Chinese long term funding for poverty alleviation and environmental improvements in Yunnan is inadequate
Risk 2: Inadequate state:provincial link established
Risk 3: Economic development given higher political ranking than reduction of environmental degradation
Risk 4: Abnormal incidence of physical shocks, e.g., earthquakes
Risk 5: High staff turnover leads to skills dissipation
Risk 6: Sustainable development and the Agenda 21 process is not given sufficient priority by Yunnan Provincial Government
Risk 7: Institutional practices limit the adoption of an integrated approach and subsequent co-ordination of activities
Risk 8: Insufficient counterpart funding leads to sub-optimum choice of pilot projects
Risk 9: Greater priority given to environmental benefits than to poverty reduction
Risk 10: Institutional support for proposed gender improvements may not be adequate

One other point with respect to risk analysis in the context of logical frameworks is that some variants of that technique (e.g., that of the German agency GTZ) have used versions where the probability of a risk—as well as its existence—is indicated within the framework itself. If the probability of a situation occurring which would jeopardize the achievement of project objectives is thought to be sufficiently high, this may be regarded as a ‘killer assumption’, around which the project must either be scrapped or re-designed.

Another UK agency which has been active in extending its analysis of risk (and which is probably the original source of the DFID approach) is the UK Treasury, in the context of the Private Sector Finance programs (where the private sector is

Figure 8
Risk Matrix: Impact and Probability Analysis

	Impact		
Probability:	Low	Medium	High
Low	4	6	1, 2, 5, 7, 9
Medium	8, 10	3	
High			

invited to participate in what are traditionally regarded as public projects). Within the Treasury's approach to PFI, considerable effort is devoted to

- identifying the full range of risks faced by a project (from planning, design and construction risks, through demand, occupancy and maintenance risks, to legislative, inflation and technology risks)
- quantifying the impact of risks (based on the Construction Industry Research and Information Association classifications of "catastrophic", "critical", "serious", "marginal", and "negligible")
- estimating the likelihood of risks (based on standard probability techniques), and
- allocating risks between different project participants, such that those who can best manage the sources of risk should bear the consequences (good or bad) of such management.

It is clearly the last of these functions which is the main purpose in the PFI context— i.e., making sure that (where possible) the ownership of risks and their consequences are transferred to the parties (public or private sector) most able to deal with them. It is then the responsibility of respective parties to take action to mitigate risk. Based on the construction of an extensive risk matrix in this way—with its emphasis clearly on allocating and transferring risks—negotiations about contracts for the private sector to be involved in public service delivery or procurement are much clearer, and the basis for the public sector comparator (i.e., the risk-adjusted cost estimate for the project to be entirely a public sector provision and against which any private bids must be compared) is entirely apparent.

Despite the innovativeness of these various techniques, it should still be noted that none of them deal with risk proper, in the sense of quantitative, probability-based techniques, or (if they do include any probability-based constituents) they do not extend such techniques as already applied—at least on occasion—by (for example) World Bank or ADB.

Risk, and the 'Harberger' Critique of Recent Applied Project Economic Analysis

While reviewing the experience of ADB and other major multilateral and bilateral development agencies with respect to the analysis of risk in the context of project economic analysis, it is impossible to avoid some of the major critiques of observed technical practices which have appeared in recent years. One of these, and one that has definite implications for practice with regard to risk analysis, is that of Harberger (1998).

One of Harberger's main points is that there has been a lack of account of risk taken in project economic work in recent years. This is partly because of the (perhaps unexpected) importance of large changes in relative prices over time (some being due to significant shocks, such as unpredictable changes in petroleum prices, and some due to longer-term trends, such as in the US$ appreciation of the late 1990s), and partly because of systematic "approval culture" which is endemic to most multilateral organizations (and which tends to consistently overstate benefits and to underestimate costs of projects in a climate of "appraisal optimism"). As a result, the relationship between what was expected at appraisal and what actually happened overall in development projects is relatively poor (the experience of the ADB projects reviewed in this Handbook largely confirms this view). Harberger also argues that because loans made by agencies such as ADB and World Bank are in effect subject to countries' sovereign guarantees and the banks' capital is not effectively at risk, these lending agencies tend to take a less serious view of risk than would, for example, private investors in similar circumstances.

As a result of what Harberger calls such "ambient pressures", a "comfortable scenario" (perhaps reinforced by organizational internal incentive structures) typically characterizes most project preparation environments, which causes a divergence between expected values at time of appraisal and ultimate project impacts. Harberger argues that better derivation of expected values at appraisal (i.e., estimation of ones more likely to represent real flows of costs and benefits) would be realized if more account were taken of risk—and in practice Harberger advocates the more widespread use of a simplified Monte Carlo simulation technique. The application of this technique would depend upon a few (he suggests four or five) values being chosen for the "key (i.e., single) variable which is most critical to the project's outcome"

in most circumstances, and an expected value for NPV being calculated based on assigned probabilities for each of these states. This approach can also be extended, so that even two or three other variables can be identified (which are in practice quite independent of one another – e.g., weather, real wage growth, traded input price), and the simulations re-run on the basis of only a few values for variables. (This approach is therefore very similar to the World Bank's "On-Farm and Minor Irrigation" project example mentioned earlier in Part III).

Harberger offers no new techniques for risk analysis *per se*, but does make a strong case for greater application of probability-based techniques, albeit in a simplified form. This is in fact what is largely recommended to improve ADB practice. ADB experience as described in Part III appears to bear out at least some of Harberger's criticisms (e.g., as regards systematic underestimation of costs, overestimation of benefits, etc.).

Summary of Risk Analysis Experience

What emerges from the review of ADB and other agency experience is that, despite the extensive academic literature describing the techniques for more quantitative approaches to risk analysis and the increasing availability of computers with which to run probability-based simulations for values of key variables, actual examples of such practice are very rare.

Within ADB, the overwhelming orientation of current practice has been towards a qualitative risk description linked to mitigating actions included in the project design. A reliance on this, plus fairly standardised sensitivity testing designed to demonstrate project robustness (survival in the 'worst case' scenario), is found across all sectors of operations.

Almost identical conclusions are drawn in relation to a review of recent World Bank practice (despite its much stronger emphasis on the utility of such techniques in its own published project economic analysis documentation), although the format and presentation of World Bank projects perhaps differ more across sectors (with a much larger number of projects being dealt with).

Within both institutions, almost the only exceptions to this situation appear to be found in the power sector, where simplified probability distributions for a few key variables are used to estimate expected returns plus estimated variability. The cited ADB port and agriculture projects, and the World Bank education project are most notable for the rarity of the application of full-scale probability techniques.

Most bilateral agencies (such as UK DFID) are now undoubtedly moving away from quantitative cost-benefit analysis generally, although it is also clear that certain qualitative techniques for dealing with risk and more centrally incorporating it within a pro-poor lending environment are emerging at the same time. Greater consideration of the expected vulnerability of poor groups in terms of the risks they face while earning their livelihoods, and how they may best be planned for in such situations, are ongoing themes of research work. Similarly, other agencies (e.g., the UK Treasury) are moving consideration of risk more towards the center of project analysis in an attempt to more properly allocate costs and benefits from risk management. Although no new techniques for extending quantitative risk analysis are yet being proposed it is possible that existing techniques may be further extended in application.

Critiques of some of the project economic analysis practices of major multilateral development agencies (based on reviews of project outcomes) include arguments that risk has not been sufficiently well dealt with in the past, and that lenders have not been rigorous enough in considering unknown future outcomes from the point of view of their borrowers (who ultimately bear the financial and economic consequences of such outcomes).

In these circumstances, perhaps the future challenge for ADB as regards risk analysis is therefore two-fold:

- as a lending institution whose interest lies in seeing that its clients (i.e., borrowing governments) are not unduly exposed to economic risks, there is scope to strengthen project design through the fuller use of risk analysis so as to ensure greater sustainability (financial, environmental, and institutional) of project effects and likelihood of project success; this can include better identification and definition of risk, and its allocation among various project participants, and
- with the increasing emphasis on lending to reduce poverty, there is a need to put the circumstances (especially as regards their vulnerability) and attitudes of those affected and targeted by projects at the heart of project economic analysis.

4

Poverty Reduction Objectives and Risk Analysis

Introduction

This Part of the Handbook considers the relationships between poverty analysis and risk analysis.

The traditional assumption about government neutrality toward risk being an appropriate basis for planning tends to break down, the more specific (i.e., concentrated on particular groups) the national project investment portfolio becomes. In addition, the consequences of uncertain outcomes (when in fact they do turn out to be low or negative) can be disastrous for poor people, whose situation is often characterized by extreme vulnerability.

With ADB's increasing emphasis on lending aimed at reducing poverty there is, therefore, a greater imperative to improve analysis of the situation of the poor with respect to uncertain outcomes from projects and policies. This involves, inter alia, more rigorous investigation of the risks affecting project returns (both to individual types of participant and to the economy as a whole) from both the point of view of planners and decision-makers, and also some consideration of the attitude of project participants themselves towards risks they may be expected to face.

This Part of the Handbook therefore summarizes the situation of the poor vis-à-vis risk, argues that some knowledge of poor project participants' attitudes is essential in making investment decisions, and considers what operational implications may follow from this for the analysis of projects' distributional and poverty impacts in both quantitative and qualitative terms.

Within the context of pro-poor lending generally, it is also the case that poor, vulnerable groups can be difficult to target development assistance towards (because of the effects of benefit leakage, for example) and therefore it may well be that pro-poor projects are inherently more risky than other projects. If this is true, then anything which can be done to strengthen economic analysis of such projects through the incorporation of risk analysis techniques is likely to educate and inform donors, as well as to lead to better projects.

Planning for the Poor, Vulnerability, and Risk Aversion

As suggested in Part II, although the techniques of probability-based risk analysis may afford a good understanding of how the variability of outcomes is related to expectations of those outcomes, this will only partially contribute to investment decision-making, and especially so in situations dealing with the poorest.

Consider two projects—A and B. In Figure 9, a probability-based risk analysis of the projects produces the CDFs for the expected NPVs (or financial outcomes at household or enterprise level) of each project. It can clearly be seen that project A is preferable to B. A is said to be "stochastically dominant" (and 'first degree' so - in that its distribution lies entirely to the right of B, i.e., at any particular level of probability its expected NPV is higher). The likelihood of either of the respective projects producing negative or low outcomes can also be immediately assessed (project A does not generate negative outcomes, unlike project B), and thus the risk to the poorest is clearly identified.

In another situation (Figure 10) the considerations are more complex. Again, project A can be said to be "stochastically dominant", in that it lies more to the right

Figure 9

CDF: Project Alternatives (1)

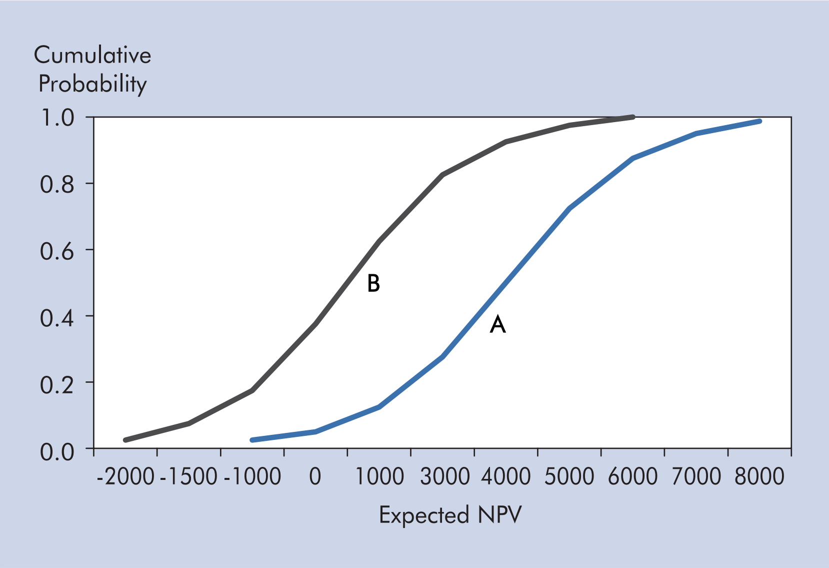
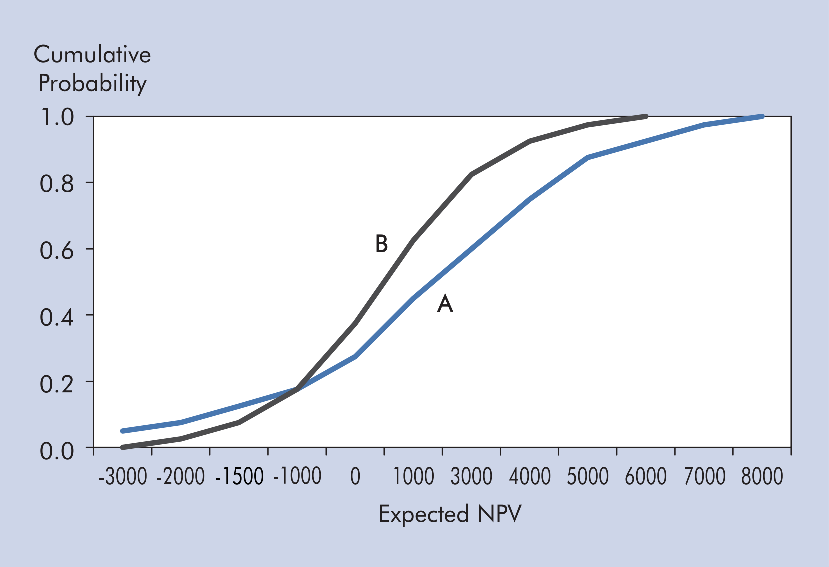


Figure 10

CDF: Project Alternatives (2)



of B than to the left. However, it is now only 'second degree' dominant. Despite its generally higher expected NPV, project A actually has greater probability of negative outcomes than project B (its CDF now crosses that of A).

This situation is not uncommon, and might well be characteristic of a situation in which new and more productive technology (e.g., agricultural, industrial) was being introduced by a project but its greater benefits depended upon (for example) water availability and management, equipment maintenance, and staff training, etc., about which some implementation doubts existed.

A question for decision-makers would therefore be about what level of risk it might be thought proper to consider imposing on a target population (in this case upon very poor people) if the consequences of failure or negative outcomes in any one year could be potentially devastating for them. Addressing this type of issue necessarily involves eliciting some kind of knowledge about poor people's risk aversion within the context of a project preparation exercise.

Poverty is usually associated with vulnerability to external shocks, cultural factors, and trends (e.g., as summarized in the DFID "livelihoods" figure in Appendix 2). In addition, and almost by definition, any situation (e.g., a proposed project) which involves the possibility of uncertain and/or negative outcomes for the poor is potentially disastrous for them—even if it would not necessarily be so for less poor populations. For example, for the poor in natural resource-based situations who have less financial reserves (if any, and especially in the typical absence of insurance) to cope with bad (i.e., low producer price) crop seasons, the consequences of failure may actually be catastrophic (e.g., property or soil loss through flooding) and/or non-reversible (e.g., loss of land to debt).

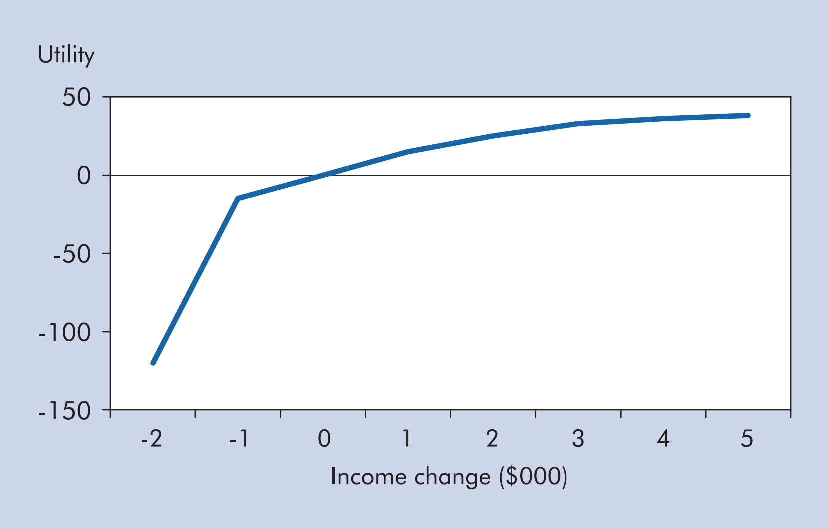
For these sorts of reasons, the poor are usually considered to be more risk averse than most sections of society. Although estimating utility functions has proved very difficult in practice (e.g., "is utility futility?"—a question which has been asked in the literature, see Part II), empirical studies have tended to demonstrate that individuals generally become very risk averse indeed when

- considering outcomes involving sums of money they are not used to dealing with, and
- when the possibilities for losses are involved.

It is often suggested that people, and especially poor people, have a "focus of loss" which causes the slopes of their utility functions to become extremely steep in the wholly negative quadrant, even though it may exhibit the more normal diminishing marginal utility in the wholly positive one.

If this is a reasonable depiction of poor populations' attitudes to uncertain outcomes, it implies that an understanding of attitudes to risk when considering

Figure 11
'Focus of Loss' Utility Function: Hypothetical Example



alternative projects or project designs is essential in investment decision-making, especially when dealing with the poorest in society.

The kind of considerations just discussed therefore implies that, when considering potential investments affecting poor people,

- as in other investment decision situations, probability-based risk analysis can usefully identify the relationships between expected project outcomes and their variability, and can be specifically used to indicate how increased predictability may be achieved, although at particular levels of cost
- such techniques can also be used to identify the likelihood of negative or very low outcomes (for individuals, groups, and for whole projects)
- the real-world consequences of any such possible outcomes for the lives of poor people can be considered, and possible mitigating action taken (e.g., safer/more robust projects designed) as a result of risk analysis, and also that
- decisions about whether or not to accept such risks necessarily involve some knowledge about risk aversion among the target population.

These sorts of conclusions have direct implications for how greater analysis of sources of risk to projects can be both quantitatively and qualitatively incorporated into existing ADB operations, especially in relation to distribution and poverty impact analysis, and also in relation to policy-based lending operations.

Poverty Reduction Objectives: Implications for Quantitative Risk Analysis

With ADB's increasing focus on lending to reduce poverty, there has necessarily been more of an analytical emphasis on measuring the distributional and poverty-reducing characteristics of operations, and in particular the recommended use of distributional analysis and the calculation of the poverty impact ratio (PIR). The increased use of such techniques has implications for how risk analysis can be used to design and assess ADB projects and policy interventions.

The methodology for distributional analysis and calculation of the PIR were originally contained in the *Guidelines*—Appendixes 25 and 26 (ADB 1997a), and have since been elaborated upon in Fujimura and Weiss (2000) and also in ADB (2001a). In essence, the methodology for estimating poverty impact in this way involves

- identifying financial and economic flows by groups of participants in a project (e.g., "consumers", "farmers", "operating entity/company", "government/rest of the economy", etc.),
- summing financial flows plus the differences between economic and financial flows (due to differences in prevailing economic prices arising through taxes, subsidies, shadow wage rate, etc.) accruing to each group,
- calculating the proportion of total benefits going to the poor in each group (knowledge of the poor's composition within each project group must be estimated), and
- summing the benefits accruing to the poor across all groups and expressing this as a proportion of total project benefits (i.e., this figure is the estimated PIR).

Calculation of the PIR involves no new data than that normally collected for a full financial and economic analysis of a project, although it does require that financial and economic costs and benefits be disaggregated by participating group and that the proportion of poor in each group be identified (a wide range of income, social, health, and other data may be used from numerous sources to assist in this definition).

In principle of course, probability distributions applied to any variables (i.e., cost or benefit items) prior to a distribution/PIR calculation would lead not just to individual (i.e., "point") estimates of financial and economic benefits by groups but to "expected" values of benefits with associated estimates of their variance, and therefore to an "expected" project PIR plus a measure of its variance. This approach has been undertaken once so far in Bank practice—in the Shen Da project described in Part III.

What is also interesting following such a calculation, however, is that the extent of variability which might emerge from such an analysis would differ between project-participating groups to the extent to which they differentially incurred costs or received benefits whose estimation derived from those variables being subjected to risk analysis. As yet, the application of comprehensive probability-based risk to model the differential impact of project cost or benefit item variability between different groups as part of a full-scale distribution/PIR estimation has not been attempted in ADB practice.

What the use of some type of risk analysis can probably and practically most usefully show in the context of poverty impact analysis is how likely it is that financial and/or economic returns may be very low or negative (i.e., ENPV<0, EIRR<EOCC) for particular groups affected by the project—typically the poor (e.g., farmers, processors, traders) who are its target population. An example of this is given in Fujimura and Weiss (2000) where differential risk exposure between project-participating groups (i.e., water authority, farmers, government) is modeled. Given ADB's increasing lending orientation towards the poor and the already described particular vulnerability of such poor populations in the face of risk exposure (as compared to national populations as a whole), the case for increased use of risk analysis is therefore made stronger than hitherto. Part V considers how this principle can perhaps be operationalized in situations where costs and benefits are quantified and valued and ENPVs are calculated for project groups and for projects as a whole.

Quantitative risk analysis could also conceptually be employed in the case of subregional projects, where the distributional analysis methodology (Adhikari and Weiss 1999) is simply a special case of general distribution analysis (only here applied to countries rather than groups within one country), but where the real level of project risk may be higher than for single country projects (e.g., because of coordination difficulties among countries and agencies, exchange rate fluctuations, etc.). Again, no examples of quantitative risk analysis have yet been undertaken for such projects.

Poverty Reduction Objectives: Implications for Qualitative Risk Analysis

In support of all projects' textual poverty analyses (e.g., in social assessments carried out at various stages) and also in situations where a PIR is not calculated for a particular project because its benefits cannot be reasonably estimated, qualitative risk analysis routinely focuses on such issues as, for example,

- extent of ability of target population to cope with risk (e.g., based on socioeconomic status indicators)
- general risks (e.g., institutional, civil) which may compromise overall project success, and
- risks of benefit leakage to non-poor groups.

Similarly, in the case of policy-based lending (PBL), the use of a poverty impact assessment (PIA) matrix is advocated to elicit the relationships and mechanisms between particular policy interventions and ultimate poverty impacts. (Policy-based lending is probably the most inherently uncertain of all lending types, in that, while the 'why' of the program is likely to be well-understood, the full range of 'what' and 'how' mechanisms in a sector is likely to be much less clear). Within this matrix, the analysis concentrates, inter alia, on economic variables that change with particular policy adjustments (e.g., removal of subsidies, imposition of user charges, etc.) and identifies the channels of their impact on the poor.

Recent consideration of how PBL and poverty reduction analysis can be more closely integrated (Bolt and Fujimura 2002) suggests that improvements to current procedures include greater use of statistical inference and risk analysis, even where the scope for quantification may be limited. Importantly, the same paper suggests that use of the PIA matrix as a design tool in a participatory fashion may help lay out options, costs and benefits from various policy alternatives in an iterative way, and thus an implicit consideration of risk by potential project participants/beneficiaries is being undertaken.

What emerges from consideration of the sorts of qualitative analysis of risk which is encapsulated in the above techniques is that project target population/beneficiaries' situations and views are being quite thoroughly canvassed, but that more could perhaps be done within such exercises to explicitly document the extent of risk aversion among such groups, as an input to planning for them (and which would be especially useful in situations of choice among various design alternatives). In other words, as well as "objective" data which may be available from other sources upon which to estimate expected values and their variance for key variables affecting project outcomes, it should be possible for project planners to gather (in the application of quite intensive and participatory data-gathering exercises) some "subjective" information about how those expected to benefit from project or policy interventions may view choices among such options.

This kind of argument is perhaps particularly applicable in circumstances where new technologies are being introduced. In these situations, project participants, such as small farmers, may well be generally enthusiastic about planting new high-yielding varieties of rice or wheat but some of them are unable to face the consequences of loss if a bad year occurs in project year 1 or 2, for example. All may be happy to accept such a risk if the expected yield is double or treble current levels, but some may well be unwilling to accept only a 40%-50% expected increase, for example–even though such an increase is clearly substantial. Understanding how farmers perceive such choices can influence

- the technical (re-)design of the intervention itself (so that its expected returns are made more stable, higher, or both)
- the way project benefits (and costs) are calculated (i.e., depending upon uptake rates), and
- the distribution of benefits (with poorer farmers given more opportunity to benefit from a redesigned intervention, for example).

Summary

Projects have differing extents of risk attached to them, and it may well be the case that projects with higher expected benefits are also more risky than some with lower benefits. Because poor people's situations are typically characterized by extreme vulnerability, exposure to very low or negative outcomes (in the acceptance of more variable project outcomes) can be catastrophic—and so there can be major issues of choice regarding appropriate levels of risk to expose target populations to in the introduction of (for example) new technologies and/or services.

Quantitative risk analysis can make clear the implications of available project choices at household, farm, enterprise, and project levels. Full-scale, probability-based risk analysis techniques could conceptually be applied to strengthen existing distribution and poverty impact analyses of projects, although it is most likely that practical applications of techniques will be limited to concentrating on describing the probability of negative returns at enterprise level.

Qualitative risk assessment based on participatory techniques (interviews, group and village discussions, etc.) is part of existing project and policy-based lending, but its scope and intensity could be increased to include gaining an understanding of target groups' attitude to risk, so that appropriate levels of risk can be incorporated in project and program design.

The increased application of both sorts of risk analysis approaches should help to strengthen project design generally, and to address poverty reduction objectives specifically.

5

Strengthening Risk Analysis in ADB Operations

Introduction

This Part of the Handbook provides some practical guidance on how to strengthen the analysis of risk in ADB operations, based on the technical material and discussion contained in Parts I to IV. Its format is primarily designed to be of use to practitioners of economic and financial analysis of all types of projects financed by ADB. (Much of the material in this Part of the Handbook is separately presented in ERD Technical Note No. 2 on *Integrating Risk into ADB's Economic Analysis of Projects* (2002).

The first section briefly summarizes the key features of the various possible techniques for risk analysis, both qualitative and quantitative.

The next sections show how strengthened analysis of risk through applying such techniques could potentially contribute to various ADB operational objectives. These are taken to be

- firstly, risk mitigation in the broadest sense (i.e., the strengthened design of individual projects such that the probability of their having an EIRR<EOCC or ENPV<0 is minimized)
- secondly, contributing to a more specific focus on ensuring the sustainability of project effects—through strengthened financial, environmental and institutional risk analyses, and
- thirdly, contributing towards the greater achievement of poverty reduction objectives through strengthened risk analysis.

This is followed by an outline of how risk analysis may contribute specifically (although in a fairly limited way) towards the formulation of policy/sector/program lending operations.

A consideration of some typical risk analysis situations sector-by-sector is then presented (again in tabular form), as within individual sectors and types of projects it is likely that similar technical/methodological, policy, and data issues will arise. The last section deals with various technical and resource implications of strengthened risk analysis being applied in practice, including some points on applying the '@RISK' package.

Summary of Risk Analysis Techniques: Applications and Limitations

In essence, what is fundamentally suggested in this Part of the Handbook is that a pragmatic approach to the use of risk analysis is warranted. Each project is unique, and the sources of uncertainty and risk it faces will be similarly unique to its own individual circumstances, and the extent to which risk can be quantitatively dealt with will also vary. It would not be appropriate to advocate hard and fast guidelines about application of particular risk analysis techniques to all projects.

Nevertheless, similar types of projects are likely to face similar analytical issues (e.g., of benefit estimation, of sustainability), and similar types of risk analysis techniques will therefore be appropriate to use across a number of project types. As a general rule,

- the greater the extent to which risk can be identified and quantified within the scope of routine project economic analysis, the stronger will be overall project design (assuming mitigating measures are put in place once the scale and impacts of known risk are clear) and the likelihood of project failure (in the sense of EIRR<EOCC) will be reduced,
- the more that risk analysis can be used to investigate the specific financial, environmental and institutional aspects of project design, the greater will be the likelihood of the sustainability of project effects over time, and
- the more comprehensively the objective circumstances and subjective attitudes of poor project participants can be taken account of in project planning, the greater chance there is of projects achieving poverty-reduction objectives.

The following table (5a and 5b) summarizes the major approaches to risk analysis which have been covered in this Handbook. It outlines their main features, the type and form of results that come from such analyses, the circumstances in which application of each of them may be likely, and also some possible constraints to their application. The table classifies the techniques according to whether they are essentially qualitative or quantitative in nature. What is apparent from the table is that there are a number of techniques for dealing with risk in project design and analysis. They range from a spectrum of simple risk identification (and linking these risks with specific mitigating measures), to subjective quantification of likelihood of event occurrence and seriousness of impact in that event, description of the nature of exposure to risk on the part of project participants and some estimation of their attitudes towards risk in particular circumstances, and (finally) to probabilistic-based estimates of project returns depending on the behavior of key variables (such estimates may derive from more or less sophisticated and data-intensive techniques).

These risk analysis techniques are of course likely to be applicable in different sorts of circumstances. The suggested elaboration of risk analysis within the existing Project Framework and the construction of a risk matrix could be applied in any project situation, while the use of continuous probability distributions based on historical observations will probably remain relatively rare (for data-intensity reasons, if not software ones), for example.

It is also important to note that the use of the individual techniques are not mutually-exclusive. For example, the risk matrix technique can identify those risks that are thought to be the most serious and/or likely to occur so that they can then be further investigated through quantitative techniques. (It is also of course the case that such variables can be identified after sensitivity testing techniques have been applied).

In essence, all the techniques attempt to identify and describe risk, and some of them try to quantify the extent of this risk. (Properly of course, it is only when some quantification has been achieved that the situation can be described as having modeled risk, rather than simply identified a source of uncertainty). Whether quantified or not, ultimately a decision about whether to accept a project in the face of the simple known existence of a risk (or of a particular level of that risk), is a subjective decision for planners and policy-makers. It remains practically impossible to derive

Table 5
Qualitative Risk Analysis Techniques

Type of Risk Analysis Technique	Main Features	
Logical framework 'risks and assumptions' elaboration	Expansion of consideration of risks within existing ADB Project Framework	
Risk Matrix Construction (and 'Risk Annex' preparation)	Construction of 3*3 (or more) cell matrix showing approximate probability of risk occurrence (high, medium, low) against seriousness of impact (high, medium, low) Allocation of risks among different project participants	
Poverty and Risk Vulnerability Assessment	Assessment of the nature and extent of target group's exposure to risk (catastrophic or not, controllable at micro level or not, reversible or not, insurable or not, etc.)	
Risk Aversion/'Focus of Loss' Estimation	Quantification of extent of target group's attitude to risk (especially any risk or risk reduction implied by the proposed project) and especially towards possible losses of incomes	

any decision rules about the acceptability or otherwise of any particular investments. However, because policy-makers and planners (within ADB and borrowing governments) are typically planning for particular groups within society, it is useful to know something about those groups' position with respect to exposure to risk and their attitudes towards any changes in that exposure which project interventions may imply in order to assess whether estimated levels of risk are acceptable to them or not.

Type and Form of Results	Likely Applications	Possible Constraints / Limitations
Textual summary of how each risk may prevent achievement of objectives at different levels of the project's objective hierarchy. Each identified risk described in more detail than at present and linked to at least one specific mitigation measure	Any project for which Project Framework is completed.	No quantitative assessment of risks' likelihood or seriousness. Barest minimum of 'risk' analysis
Risk Matrix, with individual risks numbered and discussed (along with identified mitigating measures) in separate 'Risk Annex' to RRP. Demonstration that 'killer' risks have been dealt with (i.e., that most likely / most serious is not a 'killer') Responsibilities and rewards for managing different sorts of risks assigned to those agents best able to deal with them	Any project Particularly applicable to those involving physical constructions	Subjective assessment of risk exposure only. Minimum quantification of probability; limited classification of expected impacts
Part of Initial Social Assessment prior to PPTA, concentrated in social and economic assessment during PPTA; should show how proposed project will contribute to risk exposure reduction. Part of (modified) Poverty Impact Assessment Matrix in PBL.	Any project, but especially Poverty Intervention ones PBL	Qualitative assessment only Supported by existing household survey data and also primary data collection
Application of (for example) interview-based ELCE (equally-likely certain equivalent) technique to derive estimate of risk aversion over typical income levels of those affected by proposed project intervention	New technology being introduced, especially where it is desirable to estimate likely attitudes to uptake of new but risky technologies (e.g., in agriculture) and negative outcomes may result	Relatively demanding in terms of consultant/staff and interviewee time

Table 5
Qualitative Risk Analysis Techniques *(continued)*

Type of Risk Analysis Technique	Main Features
Simplified Probabilistic Analysis (e.g., Harberger, ADB power, WB Mexico irrigation examples)	Indicates likelihood of project EIRR/ENPV being acceptable, based on consideration of key variables as determinants of project performance
Spreadsheet-Based Applications (e.g., Clarke and Low)	Use of standard spreadsheet functions (to generate random numbers and counts of observations of key variables) to produce distribution of project outcomes
'Monte Carlo' Simulation with Continuous Distributions	Classic risk analysis technique based on continuous distributions for key variables

Strengthening Project Design: Overall Economic Benefits Estimation

The primary utility of an analysis of risks faced by projects lies not in enabling choice among competing projects (as the orientation of much academic literature implies) but in the information this provides about the proposed project and its particular environment—such that consideration can be given as to how the project may be re-designed to reduce risks to an acceptable level. Ideally, the same level of expected benefits may be found to be achievable with less risk or, if risk reduction also reduces expected benefits, then the extent of that trade-off can be made clear to planners and/or beneficiaries.

Table 6 suggests some principles which can be applied to risk analysis for the purpose of overall project design, specifically in relation to the estimation of a project's overall economic benefits.

Type and Form of Results	Likely Applications	Possible Constraints / Limitations
Estimate of expected EIRR/ENPV, plus CDF of project EIRR/ENPV, with measures of variance, minimum/maximum values	Any project where key variables can be identified and simplified, and probability distributions constructed.	Results will only be as good as the distributions are realistic; statistical complexities with co-variance; availability of software (@RISK, RiskEase, etc.)
Estimate of expected EIRR/ENPV, plus CDF of project EIRR/ENPV, with measures of variance, minimum/maximum values	No inherent advantages; likely to be used only in situations where risk analysis software is unavailable	Fairly extensive familiarity with EXCEL or LOTUS required; developing non-uniform distributions by writing formulae is complex
Estimate of expected EIRR/ENPV, plus CDF of project EIRR/ENPV, with measures of variance, minimum/maximum values	Where historical/cross-sectional data exist for key variables such that continuous distributions can be fitted	Demanding in data and staff time; experience may suggest that results add little to analysis over and above use of simplified distributions

In addition to modeling the technical variables which explain a project's performance, there may also be doubt about the values which have been used in estimating the project's economic costs and benefits (i.e., the derivation of specific conversion factors–such as the shadow wage rate factor, or general conversion factors¾such as the standard conversion factor or shadow exchange rate factor). Sometimes, such factors are included within existing sensitivity testing exercises, but there is of course no reason why they could not more routinely be subject to a simplified probabilistic analysis.

Promoting the Sustainability of Project Effects

The delivery of project effects over time depends upon sustainability being built into project design. It is suggested here that risk analysis can specifically help with ensuring that ADB projects are made more sustainable in various ways. Following

Table 6
Principles in Applying Risk Analysis in Project Design

	Principles to Apply
1	Identify any risks facing the proposed project as soon as possible (i.e., pre-PPTA); include description of expected risks in first draft of Project Framework
2	Construct 'Risk Matrix' for proposed project, ranking risks according to their relative likelihood of occurrence and their expected scale of impact
3	Identify 'key' variables (e.g., quantities, unit costs, output mixtures, output prices, uptake/adoption rates, price and income elasticities of demand, etc.) which are sources of risk and determinants of project returns
4	Decide which of these variables may be subject to quantitative description
5	Identify data sources for each variable (i.e., 'objective' historical or forecasts, 'subjective' 'best guesses', expert-Delphi, etc.)
6	Construct probability distributions of key variables
7	Perform simplified probabilistic analysis (e.g., using @RISK, RiskEase, etc.) to generate CDF of expected EIRR/ENPV, minimum/maximum expected values, etc.
8	Consider whether the derivation of distributions from primary/empirical sources is justified; if so, perform probability-based analysis using such distributions
9	On the basis of results from 7 and 8, decide whether risk of EIRR<EOCC or ENPV<0 is 'acceptable'
10	*If extent of risk is regarded as 'acceptable'* – redesign may not be necessary (but check individual distributions to see if any high values are 'pulling up' the expected value of the distribution, i.e., see if positive skewness is occurring which causes average values to be substantially higher than the most likely values)
11	*If extent of risk is regarded as 'not acceptable'* – possible redesign (in particular, check to see what can be done about any low values in distributions; in particular, investigate any negative skewness, and attempt re-design to truncate distribution)

the *Guidelines*, the notion of sustainability has at least separate dimensions—financial, environmental, and institutional—and these can be approached in different ways through risk analysis. In all aspects, however, the emphasis remains on considering and modeling sources of risk and designing mitigating actions to reduce that risk if its level is considered unacceptable.

Financial sustainability risk analysis

The financial sustainability of institutions is important in most project situations. In some projects, the institutions under consideration will be financial institutions proper (e.g., state-owned or commercial agriculture banks, industrial development banks, credit unions, nongovernment organization-run operations, housing banks). In other situations they will be project executing agencies managing or providing technical or consumer services (e.g., a municipality, a commercial bus company, a state-owned plantation, a water supply and drainage authority). In all cases, lack of financial sustainability will compromise the delivery of project effects to beneficiaries, either by causing liquidity to dry up or for service provision to be suspended and/or curtailed. Risk analysis can be used to assist in designing projects so that there is less chance of this occurring.

For financial institutions such as banks, a major concern of their appraisal and consideration for participation in an ADB project is their situation with respect to risk. Following standard international banking practice, and as summarized in the *Financial Guidelines*, a number of standard measures for credit risk (borrower default), value at risk (VaR), foreign exchange risk, maturity risk, contagion risk, etc. can be derived. They generally involve some subjective estimate being made by financial analysts/PPTA teams about the probabilities of specific outcomes, typically based on a mixture of expert judgment and some forecast data. It is suggested that in many cases it would be possible to extend this analysis for at least some measures of risk to be based on probability distributions. This is especially true for the VaR, which is theoretically based on forecast values (which could be presented in probabilistic terms), and is supposed to measure

> "over a 10-day period, what is dollar amount of V such that there is only a 1% probability that a portfolio will lose more than V?" (Financial Guidelines, section 6.4.4.2)

The calculation of VaR is essential where loans are from ADB to a nongovernment-guaranteed FI, and is still useful even if the loan is treated as risk-free.

ACCION International (an American nongovernment organization) has extended the CAMEL framework ('Capital Adequacy, Assets Quality, Management Quality, Earnings and Liquidity' - see *Financial Guidelines*, 6.4.3.1) to analysis of microfinance institutions—particularly relevant in the context of increased lending to the poorest. It is the case that many of the essentially 'static' measures under CAMEL for assessing financial performance of whatever type of lending institution, are presently calculated as individual ‘point’ or ‘average’ estimates, and could usefully be turned into financial forecasts if based on distributions of variables.

In addition to these strictly financial performance risk measures, other techniques are available to assess the performance of such institutions according to a whole range of technical and management criteria. The French Development Agency (ADF) has experience in applying such techniques to developing country financial institutions, and, although they are primarily point value or logical (i.e., ‘Yes’ or ‘No’) indicator-based at present, some of the variables (e.g., for likelihood of meeting certain targets by particular dates) could be subject to probability techniques.

For project operating entities and executing agencies, the primary concern however is typically with earnings performance, cash flow, and overall FIRR and FNPV estimates. Typically, financial statements for such entities are prepared, and then standard sensitivity testing (i.e., ‘costs up 10%, 20%’; ‘revenues down 10%, 20%’; ‘revenues delayed by 1 or 2 years’, etc.) is conducted in exactly the same way as for project EIRR/ENPV estimates. What is quite apparent in this respect is of course that the modeling of risk to financial projections of project institutions is just as applicable as it is to estimates of economic benefits for the project as a whole. Instead of individual point estimates plus sensitivity testing, it is quite possible to model probabilistically (for example) such financial estimates as

- current and constant terms price projections for inputs and outputs (i.e., probabilities of current price streams and also probabilities of particular inflation rates applying)
- foreign exchange rate projections (relative appreciation and depreciation during the life of the project)
- interest rates (e.g., on loans to sub-borrowers), and
- repayment rates (e.g., from sub-borrowers).

These kinds of variables are just as amenable (and probably even more so) to probabilistic-based forecasting as any more ‘technical’ variables affecting a project’s performance. In this respect, it may be recalled that the ‘Harberger’ critique of project analysis practice of major multilateral agencies included the view that not only were estimates of project costs typically understated and estimates of project benefits typically overstated, but also that price estimates (e.g., for commodities, services, wages) and exchange rate forecasts frequently turned out to be wildly inaccurate. The greater use of quantitative risk analysis techniques, for at least some of these essentially financial variables, would be of use in ensuring project financial sustainability.

Environmental sustainability risk analysis

Another major area in which the sustainability of project effects needs to be ensured is that of impacts on the environment. Environmental sustainability of projects is ensured to the extent that environmental costs and benefits are included within the project's economic analysis. Typically, investigating and estimating the economic value of environmental costs and benefits is difficult; this is because

- biophysical relationships tend to be complicated (and thus hard to entirely capture through sampling and statistical techniques) and data are usually external to that collected during normal project preparation processes,
- market prices for many factors and project outputs do not exist, and
- different techniques for economic valuation may well lead to different results.

In addition, various biases (often stemming from professional perceptions and backgrounds) may arise in determining which impacts are important or will be large.

In general, the situation with respect to valuing environmental impacts is traditionally thought to be characterized more by uncertainty than risk, i.e., it is impossible to attach probability distributions to particular outcomes. Typical ADB practice has been that where environmental benefits have been valued at all, 'lower bounds' from estimates of 'expected values' (e.g., from carbon sequestration, from soil conservation) are quoted as the basis for benefit calculation—i.e., conservative or pessimistic forecasts are used for description of the base case. Sometimes, sensitivity testing is performed on such estimates where they are included in the base case EIRR calculation—i.e., in a manner identical to the standard treatment of other economic benefits. Occasionally a table summarizing 'Omissions, Biases and Uncertainties' in such estimates is provided—along the lines of practice recommended in ADB (1997b)—which simply indicates possible biases in the estimates for particular environmental impacts and shows what the impact on the project EIRR might be if these were corrected.

In many situations, however, it may be possible to extend this sort of analysis such that instead of simple 'uncertainty' being reflected, it would be possible to model the expected benefits in terms of their risk. The scope for the application of such techniques will vary from situation to situation, depending upon factors such as

- how familiar the analyst(s) is with the biophysical circumstances under consideration,
- the quality of primary data collected from such techniques such as hedonic pricing, contingent valuation, travel cost methods, etc., and
- the relevance and applicability of costs/benefits transferred from secondary sources (i.e., the benefits transfer method).

The utility of attempting to apply quantitative risk techniques to such situations will vary according to the relative importance of environmental impacts within overall benefits (and costs) streams—for natural resource management projects (with often large but essentially unvalued benefits) the implications of such techniques may well be significant. It may also be true that as experience with primary data collection techniques for benefit valuation within Asia expands, and as more examples of benefits transfer are applied, greater knowledge about such estimates' variability will be built-up—enabling moves towards the fuller modeling of risk rather than the simplistic description of uncertainty.

Institutional sustainability risk analysis

The last dimension of sustainability traditionally considered in project economic analysis is that of institutional sustainability. This is conceptually the dimension of sustainability which is most difficult to capture quantitatively, and few examples of quantitative benefit estimation or risk analysis from institutional performance exist. However, some recent literature suggests that institutional performance and its risk may reasonably be quantitatively estimated.

Institutional sustainability is usually considered in terms of both external factors (i.e., the project institution(s) as located within a political/policy/sector context) and internal factors (i.e., does the institution have sufficient resources to complete its tasks? is there enough technical assistance provided? etc.). One major concern which affects many projects (as well as most policy-based loans) is to what extent project institutions will be able to implement policy changes which are critical to project success, or at the very least survive in less than benign environments. A recent study of the risks associated with institutional reform in Pakistan's water sector (Dinal et al. 1997) applied a multi-stage methodology to analyze quantitatively the probability of reforms (involving the shift of policy and decision-making responsibilities away from federal and state-administered agencies and towards decentralized autonomous public utilities and end-users/water groups—as such they could expect to be contentious) succeeding or not. The key stages included evaluation of who would win and lose from the reforms, definition of reform performance levels, identification of the various ways agents would seek to influence reform implementation (and the costs of such ways), and (lastly) application of a Delphic approach to estimate probabilities of level of achievement of each reform. The Delphic approach involves asking a group of experts (in this case managers from water agencies) to assign probabilities to particular outcomes (in this case particular reform levels). Its advantage is that it provides direct assessment of risks from a collection of subjective but knowledgeable individuals and does not depend upon use of proxy measures—it could also be repeatedly performed throughout project implementation to monitor change.

What, ideally, should emerge from a Delphic-based analysis of institutional performance is therefore the best-possible guess from knowledgeable locals about the institutional environment and the probabilities of particular outcomes expressed in a quantitative form.

Supporting Poverty Reduction Objectives

In addition to more fully considering the likely distribution of overall economic benefits and also ensuring that various aspects of sustainability are built into project design, it was suggested that risk analysis could be useful in ensuring that poverty reduction objectives were better targeted. These involve not only considering the distribution of financial and economic outcomes at individual, household, farm, etc., level—in a way which is identical to describing project economic benefits and enterprise/financial institution profitability, but also considering what target groups' attitudes towards risk are, given the context of their vulnerability. The following table therefore summarizes how these various techniques can be employed to support poverty reduction; it can be seen that they attempt to marry project participants' subjective circumstance and attitudes to risk with typical probability-based risk descriptions. In addition, distribution analysis (i.e., analysis of benefits by groups participating in the project) can also be approached in terms of risk analysis.

Again, the primary focus of this sort of poverty analysis is not as an add-on to eventual project description, but should be used as early as possible in project preparation so that re-design can take place to more closely pursue ADB's poverty reduction objectives.

Risk Analysis and Policy-Based Lending

Policy-based lending is probably the area of ADB operations least disposed to techniques of risk analysis.

In contrast to project economic analysis, PBL tends to be characterized by the existence of a clear economic rationale for the intervention (i.e., the 'why' of the intervention is clear—and usually some kind of reform is envisaged within a particular

Table 7

Application of Risk Techniques for Poverty Analysis

	Risk Analysis Technique
1	**Describe textually nature and extent of vulnerability**:
	This can be approached in terms of consequences of loss (catastrophic or not), reversibility, ability for households to have any control, possibilities for insurance, etc., as part of Initial Social Assessments, Poverty Impact Assessment Matrix (in PBL).
2	**Estimate risk aversion/focus of loss for participants**:
	Estimate quantitatively to the extent possible participants' attitude to risks at different income levels, and in particular investigate 'focus of loss' for project situations (e.g., where new technology is being introduced) where possible very low or negative outcomes may have to be considered. These estimates can be derived through interview-based techniques offering participants choices between specific but certain outcomes on the one hand compared to higher but risky outcomes on the other.
3	**Estimate income/welfare impacts at individual/household/farm level**:
	Estimate the distribution of individual, household or farm incomes (based on probabilistic analysis of output quantities and prices, etc.), with the focus on the likelihood that returns may be negative or unacceptable. (This analysis should include possibilities that 'benefits leakage' will occur).
4	**Calculate distribution of poverty impact ratio (PIR)**:
	Based on the calculation of financial and economic benefits and their distribution between groups, the PIR can be calculated and so can its distribution (as long as its estimation is directly linked within the same spreadsheet as the rest of the project economic analysis). A consideration of the likelihood that the project PIR may be below an acceptable level (i.e., in relation to the proportion of the share of the poor in total population) should be provided.
5	**Justify the imposition/acceptance of any particular level of risk**:
	On the basis of steps 1-4, justify the project design in terms of its level of risk implied for the project. This is likely to differ across project situations; for example, a 25% chance of negative returns for farmers on an irrigation scheme may be acceptable if their resource base is relatively stable, but would perhaps be unacceptable to impose upon very poor communities in degraded watersheds.

sector) although the actual mechanisms and processes by which impacts on particular groups are delivered (i.e., the 'what' of the intervention) are typically less clear. It is therefore arguable that policy-based lending is inherently 'uncertain'. Quantitative relationships between individual variables and policy-based lending outcomes are not usually examined in PBL, and for this sort of reason the application of quantitative risk techniques is limited.

However, some of the techniques already described for institutional and 'subjective' poverty analysis can be applied with PBL analysis. Specifically, it is suggested that

- as the modified Poverty Impact Assessment matrix lays greater emphasis on the use of inference, interview-data, and statistical data for examining risks to which participants are exposed, in many situations of PBL, case studies of individuals, households, farms, etc., can be used to explain typical risk exposure and consequences, and likely attitudes towards risk by target groups
- techniques for quantifying the probabilities of particular levels of institutional performance be considered (as in Dinal et al. 1997) in circumstances where major reform interventions are proposed.

It is also recommended that the approaches suggested previously to link any identified risk to specific mitigation measures be followed in PBL.

Sectors and Projects: Some Typical Risk Analysis Situations

Each project design will encompass different sets of variables, many of whose actual outcomes will be unknown, and therefore the analysis of risk in that project can be as unique as each individual proposed project itself. Any proposed project may be able to show, for example, how its expected EIRR/ENPV has a particular probability of being acceptable (i.e., EIRR>EOCC, ENPV>0) depending upon values for certain key variables, or that its expected cost-effectiveness is similarly dependent on unknown but probabilistically described outcomes. It is also the case that many projects will share similar overall concerns to ensure financial, environmental, and institutional sustainability, and so the kinds of approaches to risk analysis already suggested above to address such issues could equally apply to water supply, transport, power, agriculture, etc., projects. What may be left to consider, therefore, are fairly typical 'technical' issues as they occur across different sectors and as are frequently faced by analysts.

Table 8

Project Types and Some Possible Risk Analysis Considerations

Sector/Project Type	Examples of Likely Analytical Concerns
Agriculture: Plantation/Estate	Realized tree crop yields and production; factory/mill throughput; future prices as determinants of farmers' and/or estates' incomes
Agriculture: Irrigation	Scheme maintenance; realized new and existing crop yields; crop prices; adoption/uptake rates; household and farm incomes
Forestry	Volume of harvestable wood in 7-20 years time, and price of output (e.g., pulp/wood) at that point
Fisheries	Impact of new culture technologies from aquaculture; future stocks and landings from capture; fish prices; determinants of fishermen's incomes
Environment and Natural Resources: Various	Extent of identification, quantification and valuation of indirect, non-use and option impacts of total economic value (TEV)
Transport: Rural Roads	Construction costs in difficult or unknown environment; traffic composition mixtures; extent of generated traffic and VOC savings
Transport: Highway/Toll Roads	Construction costs, price elasticity of demand for new road use; currency depreciation for loan repayment; sustainability of road authority
Transport: Railways and Ports/Shipping	Future passenger and/or freight volumes; extent of maintenance, operating costs
Energy: Rural Electrification	Operating costs, consumer price elasticity of demand
Energy: Power Generation/Transmission	Costs of inputs; poor maintenance of equipment; consumer demands for power

Potential Key Variables To Investigate	Possible Variable and Data Characteristics
Price projections; tree crop yield estimates; machinery operating capacity/efficiency	Use of World Bank commodity price projections for exports; more 'subjective' estimates for locally-consumed items; yield estimates for new crops may be based only on research trials and need some adjustment; machinery estimates based on design characteristics plus 'subjective' experience
Operating/water supply costs; yields and prices (as above); WTP estimates for water demand; adoption/uptake of new varieties	Cost estimates derived from similar schemes; WTP estimates from interviews with target groups and extent of doubt about this can be derived at same time; adoption rates can be modeled with triangular distribution as a minimum
Wood and by-product yields, losses to theft, harvest efficiency, etc. as determinants of production in future periods	Considerable doubt about point estimates of volumes and prices when wood is harvested a long time into the future; current real prices plus considerable variation should be considered
Harvest yields and fish stocks; commodity price projections and local variety	Data on yields from new technologies may be from research only – possibly exclude extreme values; fish stocks well modeled but sometimes highly mobile; price estimates may be based on comprehensive data for commodities (e.g., for tuna) or 'guesses' for local varieties
Quantities of particular biophysical impacts; alternative methodologies for benefit estimation	Knowledge of the extents of physical impacts may be reasonably well-known, but estimates of impacts' economic value can vary widely, based on both primary and secondary techniques – consider wide range of possible values
Construction cost estimates; traffic volumes by types of vehicles; VOCs	Construction costs likely to be reasonably well-known from similar projects in the same country; traffic forecasts modeled with several scenarios and associated probabilities; VOCs less well-known - but triangular distribution as a minimum
Contractor's / analysts' estimates allow for several states of costs; price elasticity of demand for road use; foreign exchange projections	Construction costs likely to be reasonably well-known from similar projects in the same country; WTP demand estimates and foreign exchange projections can be modeled with simplified probability distributions (see material on 'financial sustainability')
Costs estimates, passenger and freight forecasts	Costs based on simplified distribution estimate; forecasts of traffic demands can be modeled continuously if necessary
Capital and operating costs; consumers' demand schedules	Costs based on simplified distribution estimate; distribution of WTP estimates can be derived at same time as averages
Costs of equipment; input prices; operating efficiency; consumer demands	All subject to simplified probability distribution analysis (e.g., ADB/WB power)

Table 8

Project Types and Some Possible Risk Analysis Considerations *(continued)*

Sector / Project Type	Examples of Likely Analytical Concerns
Urban: Water Supply and Sanitation/ Wastewater /Solid Waste, etc.	Construction costs; value to consumers; willingness of authorities to pursue policy reforms (e.g., charges for service provision)
Health: Primary Care	Service uptake rates; extent of cost recovery from rural poor; benefit estimation methodology (if applied in EIRR calculation)
Education: Secondary and Post-secondary	Nature of beneficiaries' ultimate employment and the income differentials arising from such employment
Education: Teacher Training	Numbers ultimately failing to find or accept work as teachers after training

The following table attempts to indicate some of these typical project economic analysis technical concerns on a sector-by-sector/project type basis, and to indicate how risk analysis could be applied to consideration of some key variables for such projects. The table is not exhaustive in its content; it is meant to be indicative and general only.

Technical and Resource Considerations (including applying '@RISK')

The last issue to consider concerns possible implications in technical resource terms for extending the analysis of risk in ADB operations.

Again, because the application of risk analysis is likely to vary greatly in nature and extent across projects, it is difficult to develop firm conclusions about what may be needed to support any desired expansion of current practice. However, it is possible to draw out the following points related to technical and resource issues from the foregoing analysis:

- any extended application of quantitative (i.e., probability-based) risk analysis will require expansion of most project analysts' statistical skills if errors in the interpretation of results (i.e., following application of typical risk analysis software) are not to be generated. This means that some kind of essentially technical/statistical support needs to be made available within ADB

Potential Key Variables To Investigate	Possible Variable and Data Characteristics
WTP estimates; probability of success of implementing institutional reforms	Distribution of WTP estimates can be derived at same time as averages/point estimates; quantitative institutional reform analysis may be considered
Use of services and consumer demand/ability to pay; estimated WTP	Economic values, for example, DALY (disability-adjusted life year), may be contentious
Employment rates; income differentials	Can be extensively modeled with continuous distributions if necessary (see WB Mauritius example)
Policies such as school construction/funding programs; on-going institutional changes; employment rates	Institutional aspects can potentially be investigated quantitatively; modeling of employment through discrete or continuous distributions

- in such a context, it may be useful to develop some ‘typical’ project-based or sector-based models of anticipated statistical issues (e.g., to do with expected correlations between typical determinant variables) or expected distribution characteristics for particular variables
- it may also be possible to develop models for expected distributions of cost items across sectors (increasing evidence suggests that capital costs estimates for projects across a range of sectors may be log-normally distributed, for example)
- for the construction and application of either simplified, discrete probability distributions or fuller continuous distributions to generate estimates of expected EIRR/ENPV and their associated variance, the use of some kind of dedicated risk modeling software will be appropriate. While standard spreadsheets can theoretically be used for such purposes, practitioners must be prepared to either use only uniform distributions and/or develop their own distributions through complex formulae application. There is no reason for analysts to try to develop their own analytical tools when ‘off-the-shelf’ solutions are now widely available
- dedicated risk analysis packages such as @RISK have far greater functionality and ease of use than spreadsheets
- the use of @RISK is extremely simple. It can be applied to any existing spreadsheets, and primarily involves the substitution of point values in cells by user-specified distributions (in ‘input’ cells); this results in ‘output’ cells (e.g., EIRR or ENPV estimates) having distributions generated for

them, which can then be represented and analyzed both numerically and graphically

- the usual considerations of designing spreadsheets with as many individual variables specified separately therefore apply, and make the application of @RISK quite possible even for any or all variables affecting project outcomes
- there are a wide range of distribution types to choose from, and users can specify central tendency, dispersion and cut-off characteristics where appropriate; all specified distributions can be represented graphically
- distributions of various forms can easily be fitted from existing historical or time-series data, and several alternative and complementary measures of 'goodness of fit' are provided
- users can specify estimated covariance between variables in the form of an easy to use 'correlation matrix'
- typically, several thousand simulations can be processed in minutes using @RISK on a fairly standard personal computer (PC)
- alternative sampling methods for these simulations can be used, including standard Monte Carlo random sampling and the stratified Latin Hypercube sampling
- the typical time taken to apply @RISK in this way is very short – typically a couple of hours for the tasks specified above, once some form of spreadsheet model for EIRR/PIR estimation has been set up
- for most practitioners, the major issue involved in applying @RISK (or any such product) will be in correctly specifying distributions for existing or forecast data and determining appropriate extents of covariance among variables such that results for EIRR/ENPV distributions will be meaningful; while it is easy to quickly generate attractive and precise outputs from such software, the general adage applied to the use of powerful computer programs of 'rubbish in, rubbish out' still applies
- @RISK will most typically be applied to demonstrate the probability that project EIRR and/or ENPV will be unacceptable. However, it can also be used to directly generate distributions for measures of distribution and poverty impact (i.e., the poverty impact ratio, PIR), if such calculations are in cells (which @RISK will designate as 'outputs') which depend upon variables for which distributions have been substituted for point values. For this reason, it is good practice in project economic analysis to ensure that the PIR calculation (where undertaken) is seamlessly linked to the spreadsheet containing the EIRR/ENPV calculations

- for projects which are expected to be very large, marginal or particularly uncertain (e.g., perhaps because they are new sorts of lending, involve several countries, involve new technologies, etc.), the analysis of risk can be expected to figure larger than in other situations. For this reason, requirements for analysis of risk should be identified prior to PPTA and included in the PPTA scope of work; the use of a dedicated risk analysis package such as @RISK should be specified, in the same way that (for example) COSTAB is specified for financial cost estimation
- because @RISK is so easy to use, it should be applied very early in project design, specifically to investigate which variables are key determinants of project outcomes and about which more data describing such variables' distributions may be collected
- the undertaking of some form of risk-based analysis in the early stages of project design and the presentation of risk analysis results in a PPTA report would probably take only a few days work for an economist and/ or other staff.

APPENDIX 1

List of Reviewed ADB Projects and Other ADB Project Evaluation Documents

1	1698	THA	Agriculture Sector Program	23-Sep-99
2	1779	KAZ	Farm Restructuring Sector Development Program (Policy)	14-Nov-00
3	1814	PRC	West Henan Agricultural Development	19-Dec-00
4	1404	VIE	Fisheries Infrastructure Improvement	16-Nov-95
5	1656	PNG	Fisheries Development	11-Dec-98
6	1770	INO	Marine and Coastal Resources Management	26-Oct-00
7	1304	PRC	Yunnan-Simao Forestation and Sustainable Wood Utilization	30-Jun-94
8	1515	VIE	Forestry Sector	20-Mar-97
9	1643	BAN	Sundarbans Biodiversity Conservation	27-Nov-98
10	1552	SRI	Second Perennial Crops Development	25-Sep-97
11	1639	SRI	Tea Development	10-Nov-98
12	1781	VIE	Tea and Fruit Development	14-Nov-00
13	1592	KAZ	Water Resources Management and Land Improvement	17-Dec-97
14	1753	CAM	Stung Chinit Irrigation and Rural Infrastructure	05-Sep-00
15	1788	LAO	Decentralized Irrigation Development and Management Sector	28-Nov-00
16	1524	BAN	Participatory Livestock Development	19-Jun-97
17	1772	PHI	Infrastructure for Rural Productivity Enhancement Sector	31-Oct-00
18	1644	PRC	Yunnan Dachaoshan Power Transmission	27-Nov-98
19	1732	NEP	Rural Electrification, Distribution and Transmission	21-Dec-99
20	1809	PAK	Capacity Enhancement in the Energy Sector	14-Dec-00
21	1818	PRC	Wind Power Development	20-Dec-00
22	1548	MON	Ulaanbaatar Heat Efficiency	25-Sep-97
23	1901	PRC	Shen Da Transmission Interconnection	20-Dec-01
24	1715	PRC	Shanxi Environment Improvement	07-Dec-99
25	1743	MON	Second Financial Sector Reform Program	22-Jun-00
26	1735	THA	Restructuring of Specialized Financial Institutions	21-Dec-99
27	1813	IND	Calcutta Environmental Improvement	19-Dec-00
28	1554	KGZ	Education Sector Development Program	29-Sep-97
29	1637	MLD	Postsecondary Education Development	30-Sep-98
30	1718	VIE	Teacher Training	14-Dec-99

31	1447	CAM	Basic Health Services	20-Jun-96
32	1675	INO	Health and Nutrition Sector Development Program - Policy Loan	25-Mar-99
33	1749	LAO	Primary Health Care Expansion	24-Aug-00
34	1704	IND	Karnataka Urban Development and Coastal Environmental Management	26-Oct-99
35	1745	PHI	Pasig River Environmental Management and Rehabilitation Sector Development Program - Program Loan	20-Jul-00
36	1646	THA	Samut Prakarn Wastewater Management (Supplementary)	03-Dec-98
37	1755	NEP	Small Towns Water Supply and Sanitation Sector	12-Sep-00
38	1757	SRI	Water Resources Management	19-Sep-00
39	0426	MAL	Bintulu Deepwater Port	23-Nov-79
40	1559	INO	Belawan, Banjarmasin, and Balikpapan Ports	30-Sep-97
41	1584	PRC	Xiamen Port	27-Nov-97
42	1561	BAN	Jamuna Bridge Railway Link	02-Oct-97
43	1631	UZB	Railway Rehabilitation	15-Sep-98
44	1747	IND	Surat-Manor Tollway	27-Jul-00
45	1774	REG	Almaty-Bishkek Regional Road Rehabilitation (Kazakhstan Component)	31-Oct-00
46	1795	LAO	Rural Access Roads	07-Dec-00
47	1489	THA	Third Rural Telecommunications	26-Nov-96

Other ADB Project Evaluation Documents Consulted:

ADB Special Studies

Special Study of the Macroeconomic Environment and Project Performance in Sri Lanka. Report no. SS0028. December 1997.

Factors Affecting Project Performance in the Agriculture and Social Sectors: A Review of Postevaluation Reports between 1991 and 1997. Report No. SS0031. December 1998.

Special Evaluation Study on the Policy Impact of Involuntary Resettlement.
Report No. SS0041. October 2000.

Special Study: A Review of Postevaluation Findings in Thailand.
Report no. SS0005. October 1988.

Special Study: A Review of Postevaluation Findings in Indonesia.
Report no. SS0006. November 1988.

Special Study: A Review of Postevaluation Findings in Malaysia.
Report no. SS0007. December 1988.

Special Study: A Review of Postevaluation Findings in Sri Lanka.
Report no. SS0008. April 1989.

Special Study: A Review of Postevaluation Findings in Nepal.
Report no. SS0009. August 1989.

Special Study: A Review of Postevaluation Findings in Bangladesh.
Report no. SS0010. August 1989.

Special Study: A Review of Postevaluation Findings in Western Samoa.
Report no. SS0013. June 1990.

Special Study: A Review of Postevaluation Findings in Papua New Guinea.
Report no. SS0014. December 1990.

Special Study: A Review of Postevaluation Findings in South Pacific Developing Member Countries. Report no. SS0019. September 1991.

Special Evaluation Study on the Social and Environmental Impacts of Selected Hydropower Projects. Report no. SS036. December 1999.

ADB Impact Evaluation Studies

An Impact Evaluation Study of Bank Operations in the Education Sector in Indonesia. Report no. IE0022. October 1993.

An Impact Evaluation Study of Bank Operations in the Water Supply and Sanitation Sector in Malaysia. Report no. IE0028. December 1994.

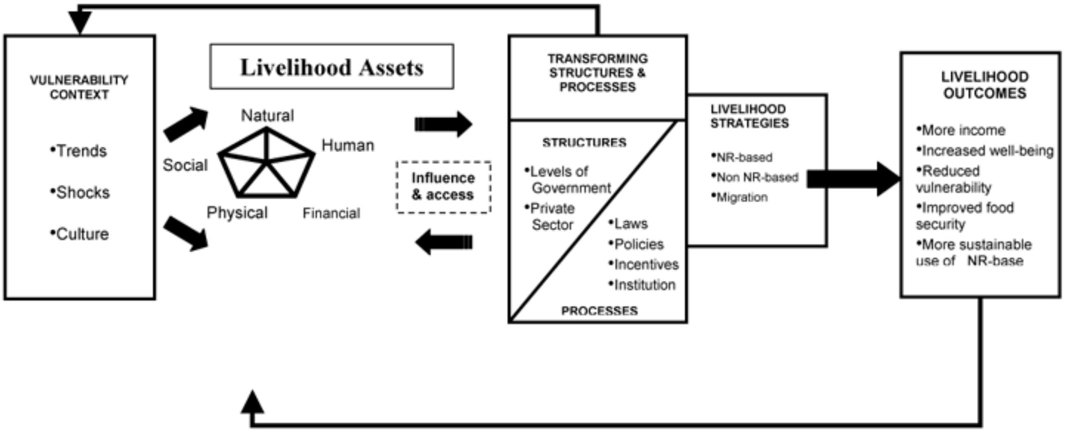
An Impact Evaluation Study of Bank's Assistance in the Health and Population Sector in Sri Lanka. Report no. IE0033. December 1995.

Impact Evaluation Study of the Bank's Benefit Monitoring and Evaluation Assistance to the Agriculture. Report no. IE0035. December 1995.

An Impact Evaluation Study of Bank Assistance to the Industrial Crops and Agro-Industry Sector in Sri Lanka. Report no. IE0038. July 1996.

APPENDIX 2

Sustainable Livelihoods Framework



APPENDIX 3

Illustration of Risk Analysis in Project Economic Analysis

Introduction

This appendix contains case studies illustrating the application of risk analysis into the project economic analysis of various ADB projects using the @RISK software. The case studies have been selected to represent a number of different types of projects and to illustrate different technical features of the application of the @RISK software.

	Project Title	Major Technical Feature Illustrated
1	Wheat Productivity Improvement Project	Substitution of triangular distribution for cell point values
2	Second Nonformal Education Project Bangladesh, 2001	Importance of correlations between variables
3	Primary Healthcare Expansion Project Lao PDR, 2000	Application of risk analysis to cost-effectiveness analysis, and choice among alternative distributions
4	Secondary Education Modernization Project Sri Lanka, 2000	Construction of variables' distributions based on secondary data, and difference between modal/most likely values and full distributional estimation
5	Shen Da Power Transmission and Grid Rehabilitation Project People's Republic of China, 2001	Risk analysis applied to poverty impact ratio
6	Wind Power Development Project People's Republic of China, 2001	Comparability of @RISK with Risk Master software

The various projects and the points which the case studies illustrate are summarised in the following table:

@RISK is an Excel add-in and was applied to the original (i.e., PPTA) EIRR calculations. The essence of @RISK is that it allows single point values in spreadsheet cells (e.g., for costs, revenues) to be substituted by user-specified probability distributions such that cells which include results (e.g., EIRR, ENPV) dependent upon those original sources can be described in terms of probability distributions of outcomes. Such distributions (for both input data and for output results) are summarised by @RISK and can be graphed and manipulated in various ways.

The case studies used the original Excel spreadsheets developed for the project economic analysis. In all cases, the analysis described for each project took only a few hours to prepare, including the acquisition of familiarity with the original economic analysis and also some exposure (without formal training) to a trial version of @RISK.

Case Study 1

Wheat Productivity Improvement Project

Introduction

The project is concerned with raising the productivity of wheat cultivation in an ADB developing member country. The economic analysis at the appraisal stage suggested that the project's EIRR was high, at 33.7%—based on PPTA consultants' 'best estimates' of a number of key variables. The application of a risk analysis software package (i.e., @RISK) to the original Excel spreadsheets can augment the economic analysis and supply further information about, and confirmation of, the project's robustness.

Sources of Risk

Values for several variables included in the calculation of the 'base case' estimate of EIRR were considered to be subject to some uncertainty. These were

- the estimated value for the shadow exchange rate factor (SERF) – little formal data upon which to estimate this parameter was available
- the amount of crop losses avoided (calculated in tonnes, deriving from estimates of proportions of current losses now saved) by the proposed project through reductions in incidence of rust on wheat
- the amount of crop losses avoided (calculated in tonnes, deriving from estimates of proportions of current losses now saved) by the proposed project through reductions in shattering of wheat grains, and
- the actual extent of areas (calculated in hectares) which would be subject to improved soil and water management regimes through the process of 'land levelling'—in project years 1 to 7.

In each case, the PPTA estimates of values were single point 'most likely' values, in effect modal values.

For the SERF, it was felt that (while the minimum value was necessarily 1) there was some doubt about the maximum value, which might conceivably be as high as 3.5. For the crop losses avoided (rust and shattering reductions), it is possible that no benefits at all might be obtained (e.g., if new technology failed to work) but also that savings of 7% and 10%, respectively could be possible. Similarly for land levelling, it was possible that no areas at all might be affected, but also that likely targets could be exceeded in very favourable circumstances.

Application of @RISK Software

The table below shows for each uncertain variable in the PPTA analysis, the original point value used in the 'base case' EIRR calculation, and the characteristics of the distributions which were substituted for these point values. In the absence of any historical or empirical data, very simple triangular (minimum possible, most likely, maximum possible) distributions were used for the present example.

Variable	Original Point Value	Type of Distribution Substituted	Minimum Value	Most Likely Value	Maximum Possible Value
SERF	2	Triangular	1	2	3.5
Rust losses avoided	3%	Triangular	0	3%	7%
Shattering losses avoided	7%	Triangular	0	7%	10%
Land levelled area (000 ha; years 3–6)	18	Triangular	0	18	25
Land levelled area (000 ha; year 7)	28	Triangular	0	28	40

Substituting the distributions for the original point values has the immediate effect of replacing the original (i.e., most likely) values with the mean values for the new distributions—and thus recalculates the 'base case' EIRR. In this case, the mean values for the four variables become as follows:

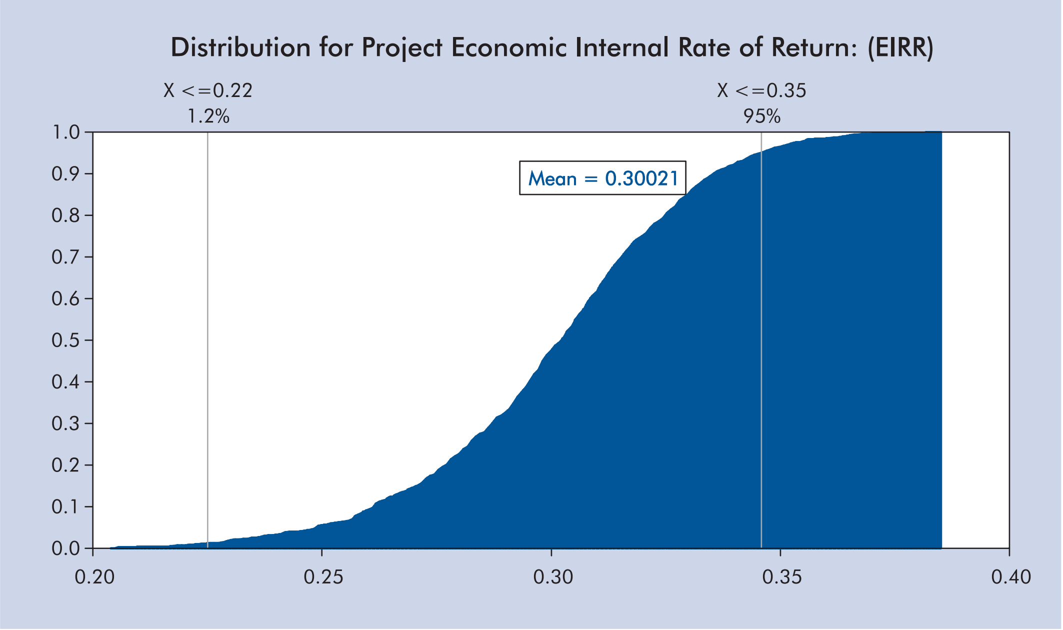
Variable	Original Point Value	New Distribution Mean Value
SERF	2	2.167
Rust losses avoided	3%	3.33%
Shattering losses avoided	7%	5.67%
Land levelled area (000 ha; years 3-6)	18	14.333
Land levelled area (000 ha; year 7)	28	22.666

Based on such mean values in the spreadsheet, the new estimated value for the project EIRR falls to 30.3% (from the original 33.7%).

Having specified the distributions, a simulation was run in which possible values for the variables were randomly sampled 1000 times using a Monte Carlo, non-stratified (i.e., not Latin Hypercube) technique. No correlation between variables was assumed to exist.

Risk Analysis Results

The main output from the foregoing analysis is a cumulative distribution function for the project's EIRR. The graph below summarises the results.



Based on the data randomly sampled from the 1000 iterations, the expected EIRR is now 30.02%. What also is apparent from this exercise is that there is only about a 1% probability that the EIRR will be below 22%.

Case Study 2

Second Nonformal Education Project (Bangladesh, 2001)

Introduction

The project was concerned with establishing an effective community-based continuing education program for poor and disadvantaged neo-literates (at least 50% of direct beneficiaries are expected to be women). Quantified economic benefits from the project are those captured privately through higher daily earnings. The economic analysis suggested that the project's EIRR was high, at 35.3% in the base case—based on PPTA consultants' best estimates of a number of key variables. Two 'pessimistic' scenarios—one of 'low wages', the other of 'low employment' were also modelled in the original analysis, as was the 'switching scenario' (i.e., a combination of low wages and low employment which would cause the project to become non-viable).

The application of @RISK to the appraisal Excel spreadsheets can augment the economic analysis and supply further information about, and confirmation of, the project's robustness. In this case, the importance of correlations between variables determining project outcomes is also apparent.

Sources of Risk

Values for several variables included in the calculation of the 'base case' estimate of EIRR were considered to be subject to some uncertainty. These were

- the proportion of participants completing the education programme
- the proportion of graduate trainees finding employment
- the days worked per month by trainees
- the months worked per year by trainees
- the incremental wage gained by trainees due to better education, and
- the number of trainees at full operation of the programme.

In each case, the RRP/appraisal estimates of values in the base case appear to be single point 'most likely' values, in effect modal values.

However, for the proportions of trainees both completing the programme and finding work, there may be some doubt about the extent of the possible downside (e.g., actual employment could conceivably be below the 'low employment' scenario modelled in the original analysis, for example, if general macroeconomic conditions deteriorated), although it is probably very unlikely that more than 95% of participants would both graduate and find work. Similarly, the potential downside of days and months worked by trainee graduates is apparent, although there are more natural upper limits likely to be in operation.

Application of @RISK Software

The table below shows for each uncertain variable in the RRP analysis, the original point value used in the 'base case' EIRR calculation, and the characteristics of the distributions which were substituted for these point values. In the absence of any historical or empirical data, very simple triangular (i.e., minimum possible, most likely, maximum possible) distributions were used for the present example.

Variable	Original Point Value	Type of Distribution Substituted	Minimum Value	Most Likely Value	Maximum Possible Value
Proportion completing training	0.9	Triangular	0.6	0.9	0.95
Proportion of trainees finding employment	0.9	Triangular	0.6	0.9	0.95
Number of days worked per month	20	Triangular	12	20	26
Number of months worked per year	6	Triangular	3	6	10
Daily wage increment due to training ($/day)	0.25	Triangular	0.15	0.25	0.35
Trainees at full operation of project	1,600,000	Triangular	1,200,000	1,600,000	1,800,000

Substituting the distributions for the original point values has the immediate effect of replacing the original (i.e., most likely) values with the mean values for the new distributions—and thus recalculates the 'base case' EIRR. In this case, the mean values for the four variables become as follows:

Variable	Original Point Value	New Distribution Mean Value
Proportion completing training	0.9	0.82
Proportion of trainees finding employment	0.9	0.82
Number of days worked per month	20	19.33
Number of months worked per year	6	6.33
Daily wage increment due to training ($/day)	0.25	0.233
Trainees at full operation of project	1,600,000	1,533,333

Based on such mean values in the spreadsheet, the new estimated value for the project EIRR falls to 28.4% (from the original 35.3%).

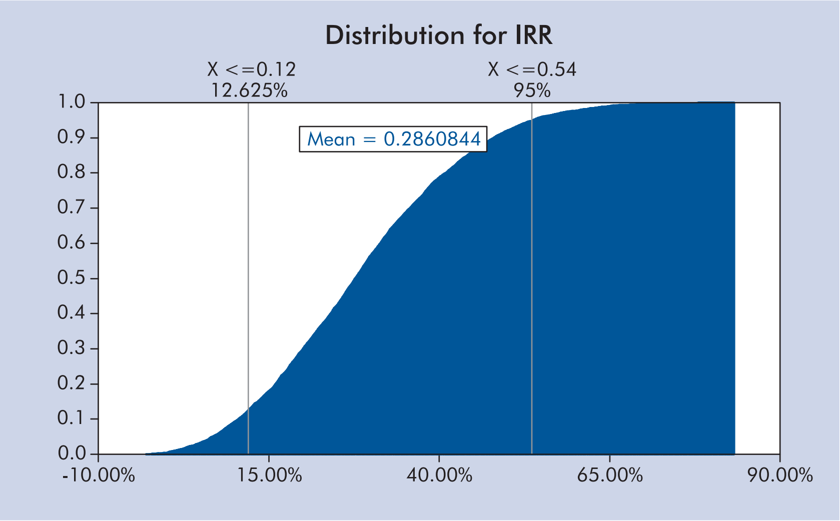
It was assumed that some correlation existed among these variables, specifically between the proportions finding employment and days and months worked. Accordingly, a correlation matrix was complied in @RISK which specified a positive 0.75 correlation between all three of these variables (implying that more people were likely to find work for more days and months as the general level of employment rose). In effect, the correlation matrix for the three variables looks like the following:

Variable	Original Point Value	Days Worked Per Month	Months Worked Per Year
Percent employed	1.0	0.75	0.75
Days worked per month	0.75	1.0	0.75
Months worked per year	0.75	0.75	1.0

Having specified the distributions, a simulation was run in which possible values for the variables were randomly sampled 5000 times using a Monte Carlo, non-stratified (i.e., not Latin Hypercube) technique.

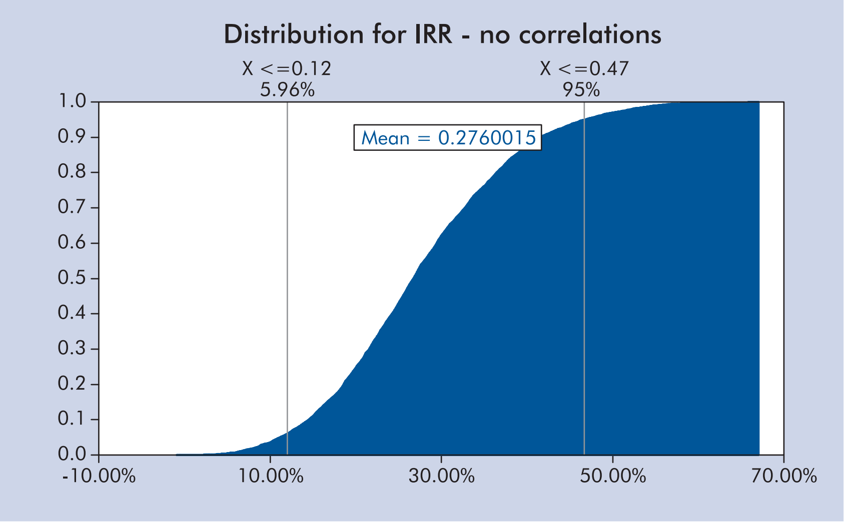
Risk Analysis Results

The main output from the foregoing analysis is a cumulative distribution function for the project's EIRR. The graph below summarises the results.



Based on the data randomly sampled from the 5000 iterations, the expected EIRR is now 28.6%. What also is apparent from this exercise is that there is about a 13% probability that the EIRR will be below the EOCC of 12%.

If the correlation is omitted from the simulation, the results are similar—the expected EIRR is slightly lower (27.6%), but the chances of project failure are now estimated to be reduced (to about 6%, or one chance in 20).



Case Study 3
Primary Healthcare Expansion Project
(Lao PDR, 2000)

Introduction

This project was concerned with expanding primary health care in eight northern provinces in Lao PDR. It was designed to target women, children, ethnic minorities, and the rural poor by providing more cost-effective and better-focused access to improved quality services.

A major feature of the economic analysis of the project is that it is based on a monetary measure of cost-effectiveness per disability-adjusted life year (DALY) saved (i.e., rather than an economic rate of return estimate). The analysis of cost-effectiveness in the RRP depended on the use of three scenarios to model doubts about the estimates of effective coverage of the project; risk analysis can be used to refine this type of approach. The application of @RISK to the original Excel spreadsheets can thus augment the economic analysis and supply further information about, and confirmation of, the project's robustness (in this case about where the expected values per cost of DALY saved lie in relation to measures of similar projects). In addition, in this case, the analysis using @RISK also tries to show the importance of properly understanding and defining variables' distributions as determinants of estimates of project economic outcomes.

Sources of Risk

The greatest difficulty in economic analysis of heath projects lies in the uncertainties of the reduction of disease burden, or saving in the otherwise lost DALYs. The uncertainty arises both from doubts about changes in the incidence of disease which project interventions bring and also about the actual coverage of service delivery which the project will achieve.

The economic analysis contained in the project's RRP deals with this uncertainty by modelling three scenarios ('low', 'moderate', 'high'), each of which is characterised by a differential proportion of the target population (grouped by women, children and the total population) which is covered by the primary health care (PHC) services. The table below shows details of such estimated values for the early years of the project.

As a result of the total costs of the project being distributed over different numbers of estimated DALYs, the economic and financial costs of each DALY differ

DALYs saved under:	2001	2002	2003	2004	2005	2006
Low Scenario	–	8,139	16,668	25,603	34,956	44,744
Moderate Scenario	11,922	24,417	37,504	51,205	65,543	67,116
High Scenario	15,896	32,556	50,005	68,274	87,391	89,488

by scenario, and range from $45.82 per DALY under the ‘low’ scenario to $21.09 per DALY under the ’high’ scenario (the ‘moderate’ scenario value is $28.11).

Application of @RISK Software

The data in the original spreadsheets were used for the distribution-based calculations. The population coverage estimates for women, children, and the total population contained in the ‘moderate’ scenario were used as the basis for the estimation of two sorts of probability distributions. These distributions were

- a normal distribution, with the mean being the value from the ‘moderate’ scenario and the standard deviation being 25% of the mean, and
- a triangular distribution, with the minimum value being the ‘low’ scenario estimate, the most likely (i.e., modal) value being the ‘moderate’ scenario value and the maximum value being the ‘high’ scenario value

It may be argued that either or both of these distributions might reasonably model the uncertainty with respect to possible values for project coverage of the population. Both exploit data points from the original PPTA/RRP work, are centrally fixed on the original ‘moderate’ value estimates, and appear to have believable measures of, or limits to, dispersion.

Accordingly, the original point values in the cells for the moderate scenario (see below, for early years of the project) were substituted by the particular normal distribution just described and then (in a second separate simulation) by the triangular distribution also described.

As in the other case studies, when distributions are substituted for point values the original cell point value is replaced by the mean of the particular distribution. In the case of the normal distribution replacement the mean is the same as the original ‘moderate’ values—and so the final cost/DALY estimate is unaffected. However, with the triangular distribution substitution the effect in this case is to reduce the mean estimate, and thus to increase the estimated cost/DALY.

Moderate Scenario Population Estimates

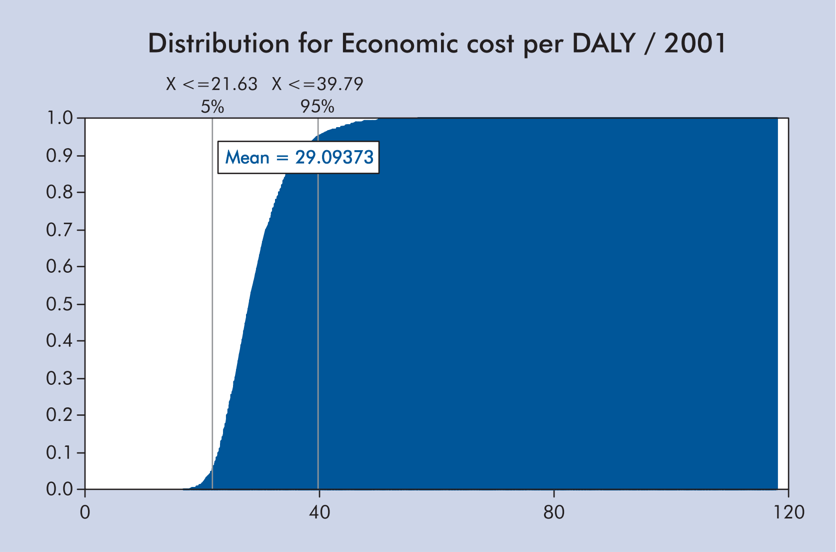
	2001	2001	2003	2004	2005	2006
Women 15–44	12,600	25,805	39,636	54,116	69,269	70,931
Children 0–4	9,355	19,158	29,427	40,178	51,428	52,662
Total Population	62,944	128,909	198,005	270,343	346,039	354,344

Having specified the distributions, two simulations were run in which possible values for the variables were randomly sampled 5000 times using a Monte Carlo, non-stratified (i.e., not Latin Hypercube) technique.

Risk Analysis Results

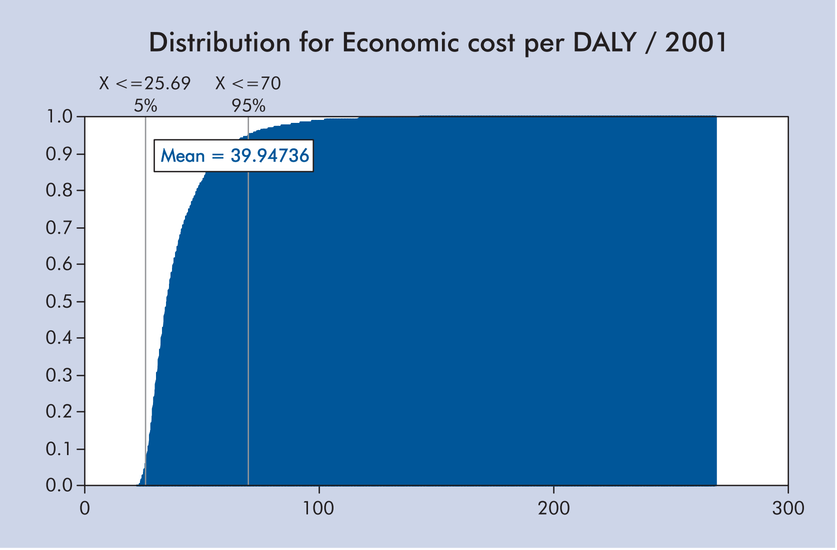
The main output from the foregoing analysis is a cumulative distribution function for the project's cost-effectiveness, measured in terms of the cost per DALY saved, for each of the two types of distribution. The graphs below summarise the results.

The first graph shows the cumulative distribution function for the project's cost per DALY based on the normal distribution. The mean of the distribution (at $29.09) is very close to that of the original moderate scenario. It can also be seen that there is only a 5% chance that the actual cost of a DALY would exceed $40 (well within acceptable ADB parameters).



The second graph shows the same result, but now based on the triangular distribution instead of the normal one. The mean value for the distribution in this case is some 33% higher than previously (at just under $40), and the 5% upper value unlikely to be exceeded is now some $70.

Although the particular project design in this instance may find both results within acceptable limits, this example does highlight the critical importance of specifying variables' distributions correctly; even two apparently reasonable-looking distributions for the same variables can produce quite different results in terms of estimates of project costs or returns.



Case Study 4

Secondary Education Modernization Project (Sri Lanka, 2000)

Introduction

The objective of the project was to make Sri Lanka more economically productive and competitive by modernizing the secondary education system through improved curriculum instruction, school-based assessment (SBA), and school-based management (SBM). Specifically, the project design aimed to increase percentages qualifying to enter grade 12 from 35% to over 50% by 2005, increase the percentage qualifying to enter grade 12 from 15% to 20% for rural students by 2005, to implement SBA and examination reform by 2005, and implement a SBM system in all secondary schools by 2005.

The project economic analysis calculated an EIRR based on incremental earnings of those receiving improved education in a competitive labor market. This is taken as a proxy for the incremental social benefit to the country as a whole. Because of doubts about actual examination pass rates and income differentials between non-educated and educated workers, a sensitivity analysis was conducted using different values for these variables.

In this case study, the analysis using @RISK shows how data from other sources (e.g., from similar projects in other countries, from labor surveys, etc.) can be used to construct probability distributions which can then be substituted for the original point values. It also shows the implications for estimates of project returns based on point values as compared to those based on distributional data.

Sources of Risk

In the case of this project, major sources of uncertainty include

- differences which will be achieved in earnings between those with upper secondary, 'O' level (O/L) and 'A' level (A/L) education compared to laborers with no schooling, and
- examination pass rates at grades 11 and 13.

The project sensitivity test results in this respect are summarised in the following table. It can clearly be seen that the returns from the project may be affected adversely if there is a fall in the O/L and A/L pass rates.

Sensitivity Test	EIRR
Base case	20%
Reduce O/L pass rate from 50% to 45% and A/L pass rate from 60% to 55%	11%
Increase O/L pass rate from 50% to 55% and A/L pass rate from 60% to 65%	27%
Reduce income differentials by 10% between worker with upper secondary education and O/L worker, and between O/L worker and A/L worker	18%

Application of @RISK Software

In the previous case studies, @RISK generated distributions for variables in cells based on either one or two user-specified characteristics (i.e., mean and variance/ standard deviation) or a few data points (e.g., minimum, maximum and most likely – in the case of the triangular distributions). In this case study, hypothetical data from secondary sources covering examination pass rates and workers' earnings are entered into the spreadsheet and distributions are then fitted to the variable(s) in question. The software user is able to choose between different types of distribution to be fitted (e.g., normal, lognormal, beta, exponential, etc.) based on various measures of the 'goodness of fit' to the available data (including Chi-square, K-S and A-D tests).

The data used for the project economic analysis base case is contained in the following table:

Sri Lanka: Secondary Education Modernization Project: Base Case Basic Data	
Wage of laborer with no schooling 1,025.36 x 4 x 12 x 115/95	59,579
Wage of laborer with upper secondary education 1,336.36 x 4 x 12 x 115/95	77,591
Wage of employed O/L worker 1,822.45 x 4 x 12 x 115/95	105,894
Wage of employed A/L worker 2,426.40 x 4 x 12 x 115/95	140,987
Grade 11 exam pass rate Implementation year 1 (and without project) Implementation year 5	36% 50%
Grade 13 exam pass rate Implementation year 1 (and without project) Implementation year 5	48% 60%

The earnings data come from the *Household Income and Expenditure Survey* (1995/96) conducted by the Department of Census and Statistics, and the figure quoted for A/L wages (SRL Rupees 140,987) is presumably an average (mean) value for the country as a whole. For simplicity, the risk analysis will look more closely at variability associated with only the earnings of A/L workers and with grades 11 and 13 pass rates, although it could equally be applied to any variables in the project economic analysis.

For illustration purposes, suppose historical data were available (for example) for wages of A/L workers (e.g., from cross-sector employment surveys) and grade 11 and 13 pass rates (e.g., from similar projects in other countries implemented in recent years) in the following form:

Earnings of A/L workers:						
142000	141370	139800	146000	142850	136000	141100
141200	141350	140980	148000	135500	141500	143100
140800	130600	144500	143000	138700	138000	140987
142100	141700	139500	143500	141000	139500	143000

Grade 11 pass rates:

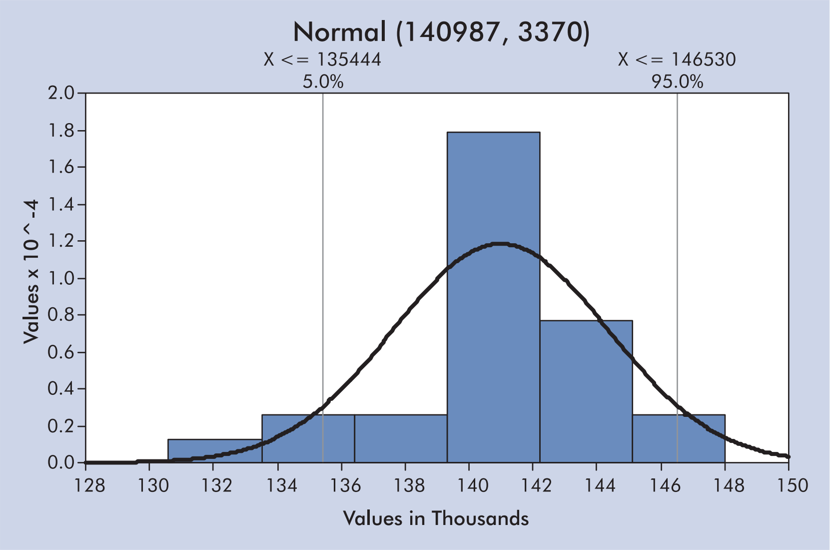
50	45	53	49	48	52
52	50	56	45	50	50

Grade 13 pass rates:

60	55	63	59	58	62
62	60	66	55	60	60

@RISK allows a distribution to be fitted by users to such observations. The following chart shows a normal distribution fitted to the earnings data. The distribution has an identical mean to the original spreadsheet point value, and a (relatively small) standard deviation of 3370. The software generates distributions of different types, and ranks them according to various measures of goodness of fit. The default measure is the Chi-square value.

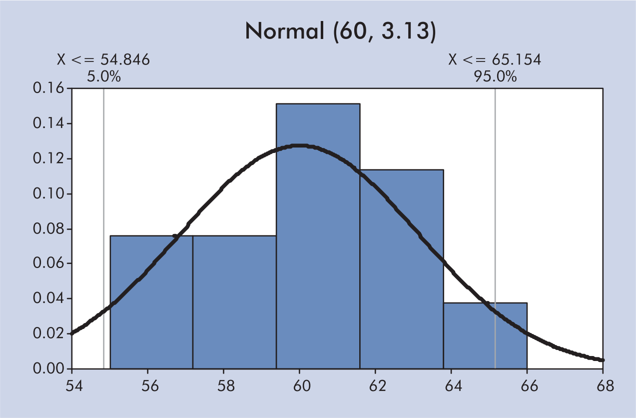
It should however be noted that different measures of goodness of fit (e.g., the Kolmogorov-Smirnov statistic, the Anderson-Darling statistic, etc.) may rank distributions differently. Considerable care should therefore be exercised in interpreting the statistics and applying particular fits. In this case, the normal fitted distribution has been chosen because its mean is identical to the original point value data, and the only (very slightly) better fit in terms of its Chi-square value—a beta (general) fit—has a different predicted mean (on both other major estimates of goodness of fit—the K-S and A-D statistics—the normal fit is better).

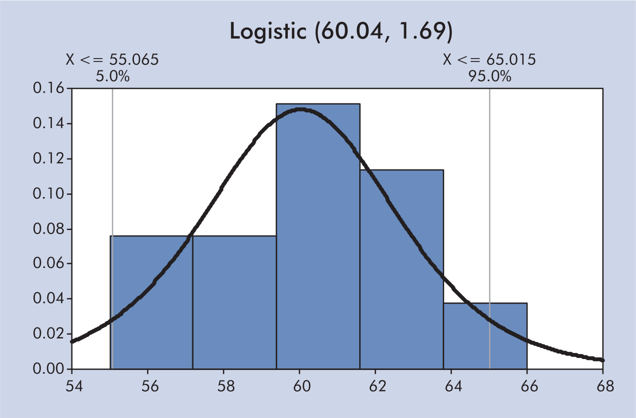


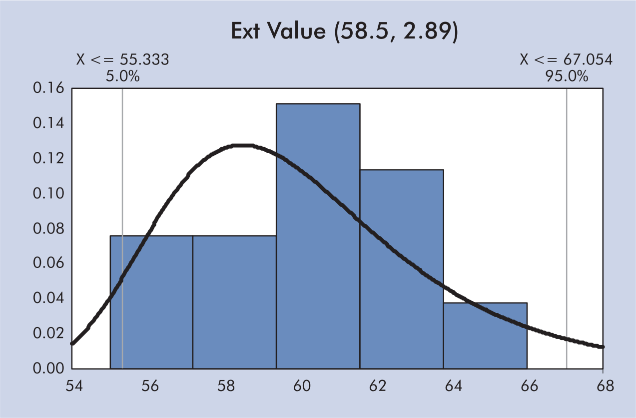
For the examination pass data, again normal distributions (for each of the grade 11 and 13 pass rates) have been chosen to replace each of the original point values because the mean of these distributions alone among the available choices is the same as the original values, although in this case 'Logistic' and 'Extvalue' distributions have perhaps slightly better fits based on their K-S and A-D measures—even though all three distributions' Chi-square values are the same.

The following charts show (as an example, the grade 11 values in the distribution of that variable are identically-distributed but 10% lower in all cases) the original grade 13 examination pass rate data grouped by class interval and the various fitted distributions of different types:

Having specified the distributions for the three variables, a simulation was run in which possible values for the variables were randomly sampled 5000 times using a Monte Carlo, non-stratified (i.e., not Latin Hypercube) technique.





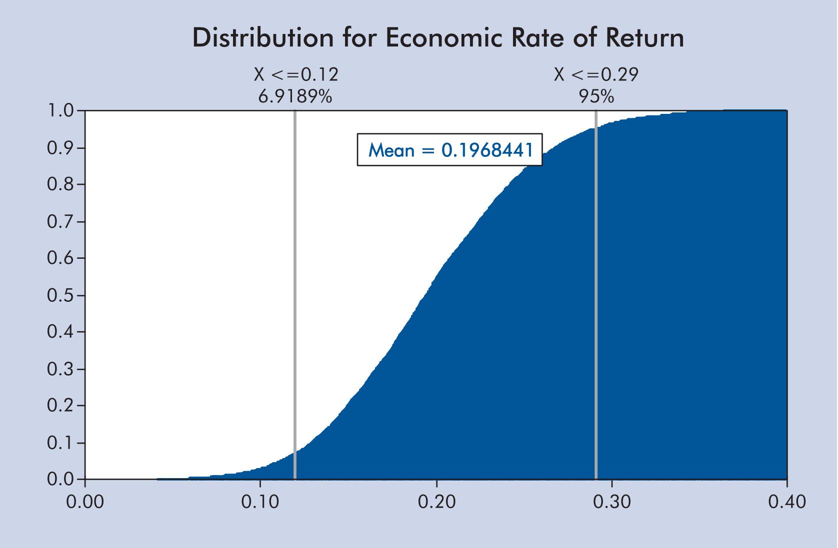


Risk Analysis Results

The distribution which results for the EIRR on this basis has a mean which is very close to the base case mean—unsurprisingly, given that the selected variables are modelled to be normally distributed around identical mean values to those in the original spreadsheets. Based on the (hypothetical) distribution data it appears that there is only about a 7% chance that the EIRR for the project would be below the EOCC of 12%.

The examination pass rate data in this case study can also be used to demonstrate one other point about risk (i.e. probability-based) analysis as applied in such situations. In many project analysis circumstances, it is not clear whether point value data in spreadsheet cells represent the analyst's 'best guesses' of 'most likely' (or somehow 'typical') values or whether it represents average/mean expectations. In fact great differences in results can emerge in calculations of returns, depending upon how such estimates are used.

Consider the following example (hypothetical – and unrelated to the actual project under consideration). The



estimates of exam pass rates in the original data (i.e., 50% for grade 11 and 60% for grade 13) may in fact represent the analyst's best guesses of 'most likely' outcomes (i.e., the single value from among a range most likely to occur, unadjusted for any probability of occurrence). The following distribution of observations in such a case may suggest that values of 50% and 60% passes are the values most likely to occur (in nine out of twelve observations), even though other (lower) values can also occur.

Grade 11 pass rates

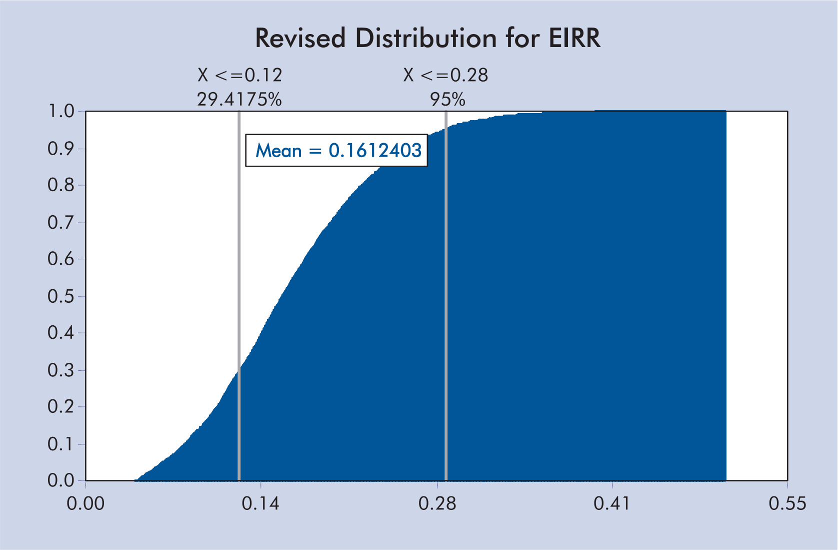
50	50	50	50	50	50
40	40	40	50	50	50

Grade 13 pass rates

60	60	60	60	60	60
50	50	50	60	60	60

If estimates of EIRR/ENPV, etc. are based on the most likely point values alone (i.e., 50% and 60%) we get the original base case estimate of 20% EIRR. If we construct probability distributions around such values with the original points as their mean we get a similar expected EIRR value and a distribution as shown in the chart immediately above.

If, however, we use the actual data from observations as just shown in the last table (and which could have been used to derive the original estimates based on a ‘most likely’ or modal basis as opposed to a mean-based one) the mean and distribution of EIRR are as follows. It can be seen that not only is the estimate of the expected EIRR proportionately lower, but that the risk of project failure has now increased over fourfold (to 29% from about 7%).



Case Study 5

Shen-Da Power Transmission and Grid Rehabilitation Project (People's Republic of China, 2001)

Introduction

The project aims to increase the capacity and efficiency of electricity transmission from the northeastern part of the PRC to the southern part of Liaoning Province, thereby increasing the availability of electricity and reliability of the electricity transmission and distribution systems in Liaoning Province. Furthermore, an integrated regional grid that will enable restructuring of the power sector in Liaoning Province will be developed. The major economic benefits for the project are efficiency improvement (reduced losses) and increased supply.

RiskMaster was used on the original Excel spreadsheets to supply further information about the PIR of the project. For this case study illustration, @Risk was used. The dimension of risk in project analysis is of significance in discussions of poverty since the poor are the most vulnerable to unexpected unfavorable outcomes. A reduction in vulnerability is a central element in a poverty reduction program and a sharing of risk across a wide portfolio of projects may still leave the poor excessively exposed. Hence, for important, poverty-focused projects for which monetary estimates of costs and benefits to the poor are feasible, it is desirable that both the probability of overall project failure and the probability of a negative outcome for the poor be assessed.

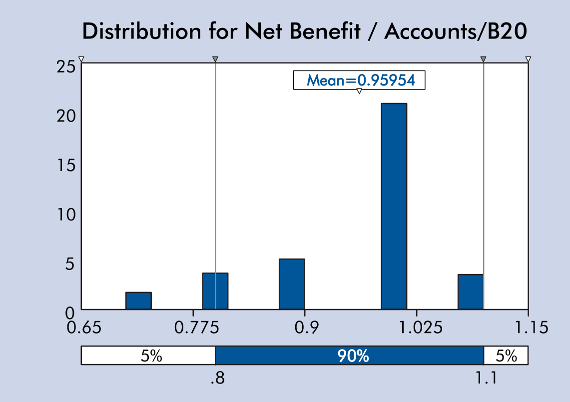
Sources of Risk

The risk analysis was carried out for the PIR of the Project to ensure that there would be no negative outcome for the poor. Five variables for the PIR analysis have been considered to be subject to some uncertainty. These were:

- net financial benefits
- net economic benefits
- the share of consumer surplus to the poor
- the share of the Government net benefits to the poor
- the share of labor surplus to the poor.

In each case, the RRP estimates of values were single point ' most likely' values.

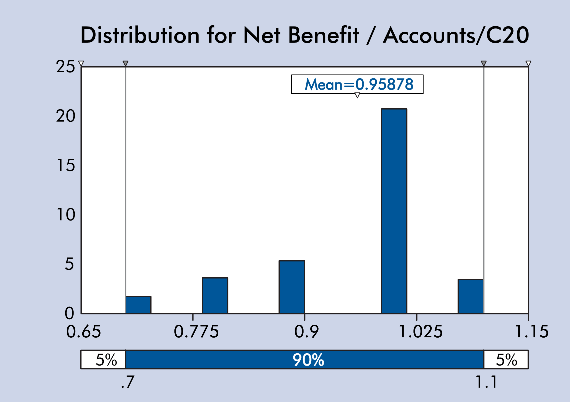
Risk Variables Report



Risk Variable No. 1

Net Benefit of Financial Accounts

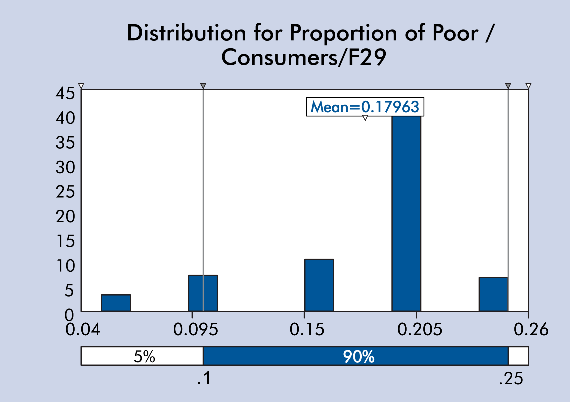
Probability distribution: DISCRETE				
5%	10%	15%	60%	10%
0.7	0.8	0.9	1.0	1.1



Risk Variable No. 2

Net Benefit of Economic Accounts

Probability distribution: DISCRETE				
5%	10%	15%	60%	10%
0.7	0.8	0.9	1.0	1.1

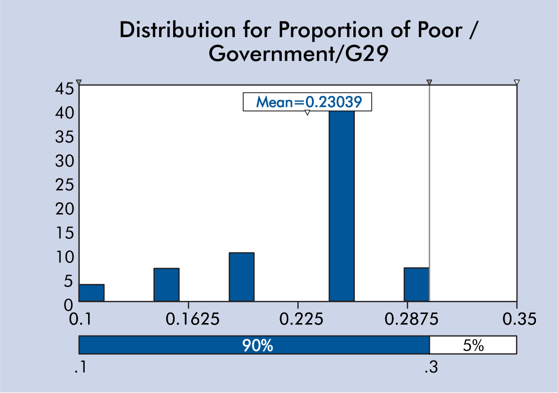


Risk Variable No. 3

Proportion of Poor for Consumers

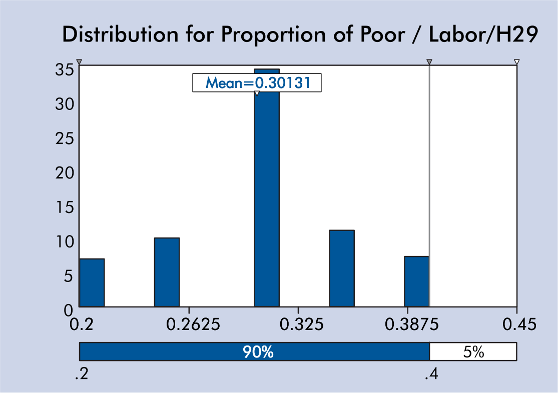
Probability distribution: DISCRETE				
5%	10%	15%	60%	10%
0.05	0.10	0.15	0.20	0.25

Risk Variables Report *(continued)*



Risk Variable No. 4
Proportion of Poor for Government

Probability distribution: DISCRETE				
5%	10%	15%	60%	10%
0.10	0.15	0.20	0.25	0.30



Risk Variable No. 5
Proportion of Poor for Labor

Probability distribution: DISCRETE				
5%	10%	15%	60%	10%
0.20	0.25	0.30	0.35	0.40

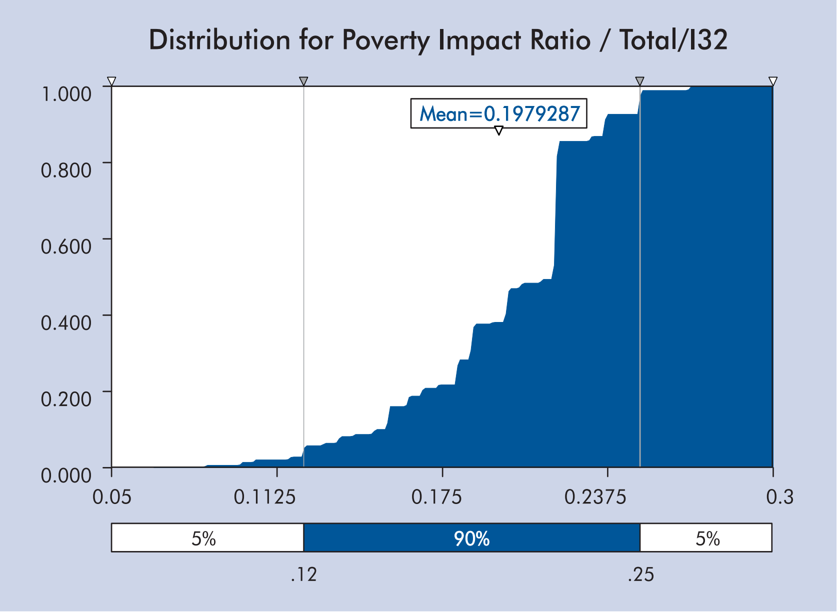
Application of @RISK Software

The probability distributions attached to the selected variables and graphed below take into account past ADB experience in power projects in general and the project/country circumstances in particular. The table below shows the five selected variables including the original point value used in the PIR calculation, the assumed value ranges, and the assigned probability distributions. The risk analysis was carried out using the Monte Carlo simulation technique. The results were based on 5000 iterations; no correlation between variables was assumed to exist.

Risk Analysis Results

The results of risk analysis have shown that the expected PIR, based on the weighted average of all simulated combinations is 19.8% (with a standard deviation of 3.6%), slightly lower than the base case value (i.e., without the consideration of risk). PIRs range from a minimum of 6.6% to a maximum of 26.9%.

The probability of the PIR falling below the value for the poor as a proportion of the population as a whole, and thus not having a pro-poor impact, is estimated to be about 12%.



Case Study 6

Wind Power Development Project (People's Republic of China, 2000)

Introduction

This project will produce electricity in an environment-friendly manner and increase the share of wind-based electricity in overall power generation through the establishment of three grid-connected wind farms in the Xinjiang Uygur Autonomous Region and Heilongjiang and Liaoning provinces. It will avoid emissions of SO_2, NO_X, TSP, and CO_2 associated with conventional thermal power generation.

The calculation of the EIRR covered 1999-2022, and used constant 1999 prices, and a discount rate of 12%. Tradable commodities were valued at border prices at the prevailing exchange rate. Nontradable commodities were valued at shadow prices using a mix of standard and specific conversion factors. The main benefits are the incremental supply of electricity, valued through the avoided costs of supplying an equal amount of electricity as the wind-based electricity to be produced under the Project, and environmental benefits.

Risk analysis on the original Excel spreadsheets was originally carried out using Risk Master. In this case, the analysis has utilized @RISK to test its comparability to Risk Master.

Sources of Risk

Project parameters that were selected as risk variables based on the sensitivity analysis include:

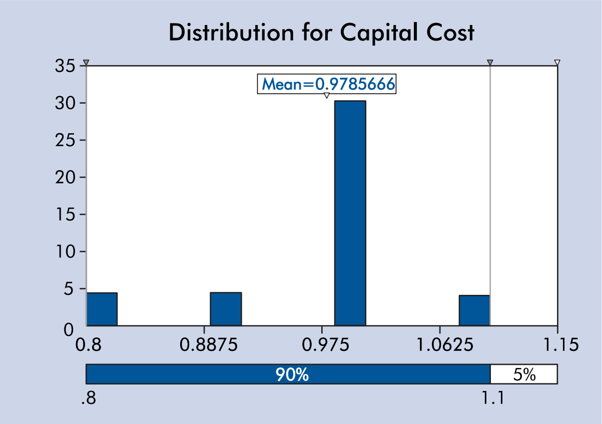
- capital cost
- generation
- foreign exchange rate
- commission date
- avoided cost.

In each case, the RRP estimates of values were single point ‘ most likely’ (i.e., ‘modal’) values.

Application of @RISK Software

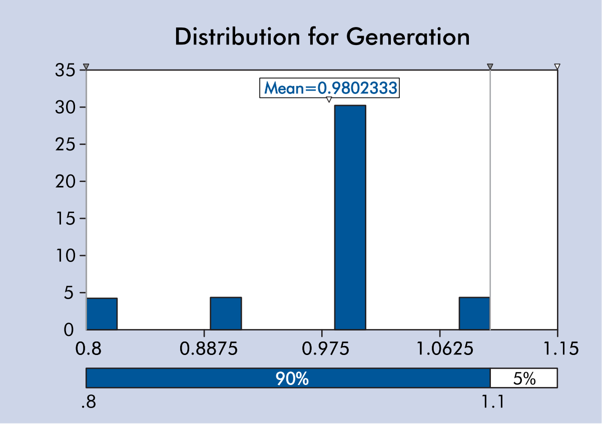
The probability distributions attached to the selected variables take into account past ADB experience in power projects in general and the project/country circumstances in particular, as well as extensive discussions with the executing agencies and other relevant agencies. A Monte Carlo simulation was used to model the likely distribution of these risk variables and the associated EIRRs. The table below shows the five selected variables including the assumed value ranges and the assigned probability distributions.

Risk Variables Report



Risk Variable No. 1
Capital Cost

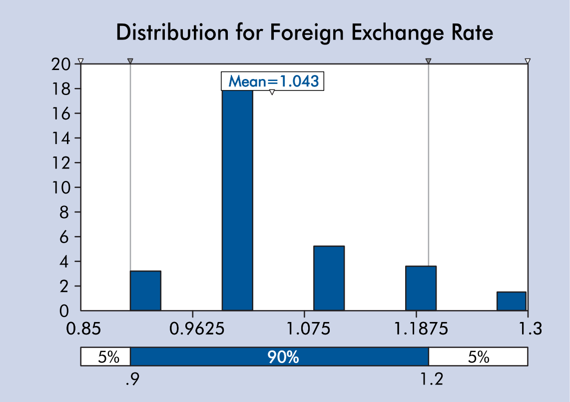
Probability distribution: DISCRETE			
10%	10%	70%	10%
0.8	0.9	1.0	1.1



Risk Variable No. 2
Generation

Probability distribution: DISCRETE			
10%	10%	70%	10%
0.8	0.9	1.0	1.1

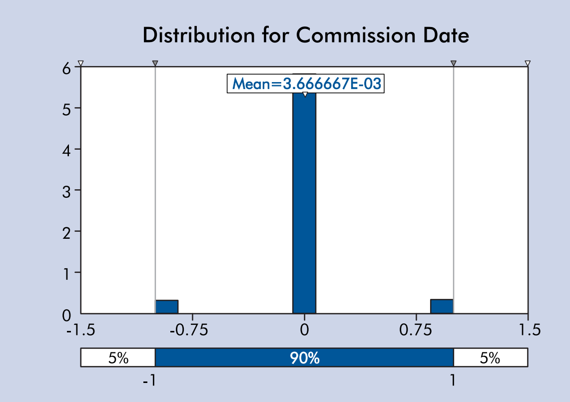
Risk Variables Report *(continued)*



Risk Variable No. 3

Foreign Exchange Rate

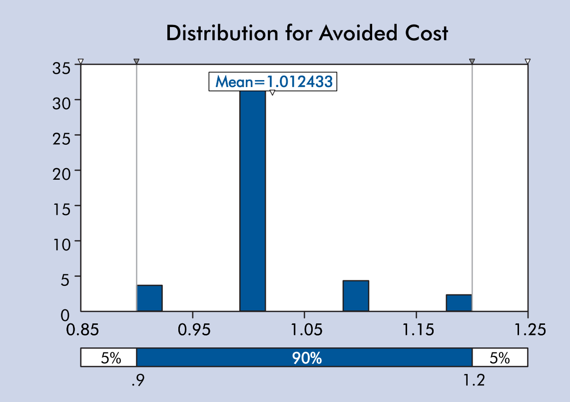
Probability distribution: DISCRETE				
10%	60%	15%	10%	5%
0.9	1.0	1.1	1.2	1.3



Risk Variable No. 4

Commission Date

Probability distribution: DISCRETE		
5%	90%	5%
-1.0	0.0	1.0



Risk Variable No. 5

Avoided Cost

Probability distribution: DISCRETE			
10%	75%	10%	5%
0.9	1.0	1.1	1.2

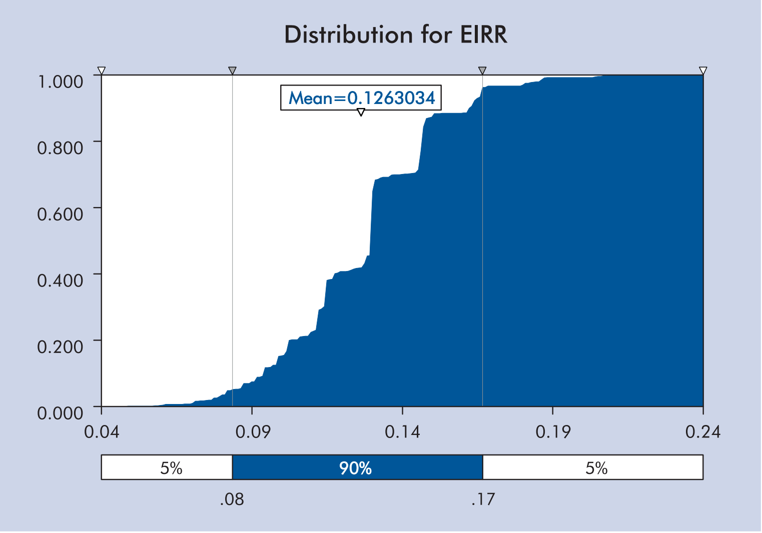
The results were based on 3000 iterations; no correlation between variables was assumed to exist.

Risk Analysis Results

The results of risk analysis using @RISK shows that the expected EIRR, based on the weighted average of all simulated combinations is 12.6% (with a standard deviation of 2.5%)—about 0.3% lower than the base case EIRR of 12.9% (without consideration of risks). The EIRRs associated with assumed probabilities range from a minimum of 4.8% to a maximum of 22.6%. For this project, the probability of the EIRR to be below the considered discount rate of 10% is 15.4%.

The expected EIRR using Risk Master produced a weighted average of 12.7% with a standard deviation of 2.4%—involving only a slight difference of 0.1% between the two software programs.

EIRR (Local Env. Only)	
Expected value	12.6%
Standard deviation	2.5%
Minimum	4.8%
Maximum	22.6%
Probability of negative outcome	0.0%



References

Adhikari, R. and J. Weiss. 1999. *Economic Analysis of Subregional Projects*. EDRC Methodology Series No. 1. March 1999. Manila: ADB.

Anderson, J.R. 1974. "Sparse Data, Estimational Reliability and Risk-Efficient Decisions." *American Journal of Agricultural Economics*.

Arrow, K. and N. Lind. 1970. "Uncertainty and the Evaluation of Public Investment Decisions." *American Economic Review*. Volume 60 No. 3.

ADB. 1979. Report and Recommendation of the President to the Board of Directors on a Proposed Loan to Malaysia for the Bintulu Deepwater Port Project. Manila.

ADB. 1997a. *Guidelines for the Economic Analysis of Projects*. Manila: ADB.

ADB. 1997b. *Workbook on the Economic Valuation of Environmental Impacts.* Manila: ADB.

ADB. 2000a. Report and Recommendation of the President to the Board of Directors on a Proposed Loan to Sri Lanka for the Secondary Education Modernization Project. Manila.

ADB. 2000b. Report and Recommendation of the President to the Board of Directors on a Proposed Loan to the Lao People's Democratic Republic for the Primary Health Care Expansion Project. Manila.

ADB. 2000c. Report and Recommendation of the President to the Board of Directors on a Proposed Loan to the Philippines for the Infrastructure for Rural Productivity Enhancement Sector Project. Manila.

ADB. 2000d. Report and Recommendation of the President to the Board of Directors on a Proposed Loan to the People's Republic of China for the Wind Power Development Project. Manila.

ADB. 2001a. *Handbook for Integrating Poverty Impact Assessment in the Economic Analysis of Projects*. Manila: ADB.

ADB. 2001b. Report and Recommendation of the President to the Board of Directors on a Proposed Loan to the People's Republic of China for the Shen Da Power Transmission and Grid Rehabilitation Project. Manila.

ADB. 2001c. *Guidelines for the Financial Governance and Management of Investment Projects Financed by the Asian Development Bank.* Manila.

ADB. 2001d. Report and Recommendation of the President to the Board of Directors on a Proposed Loan to Bangladesh for the Second Nonformal Education Project. Manila.

Belli, P., J. Anderson, H. Barnum, J. Dixon, and J. Tan. 2001. *Economic Analysis of Investment Operations: Analytical Tools and Practical Applications*. Washington D.C.: World Bank Institute.

Bolt, R. and M. Fujimura. 2002. *Policy-based Lending and Poverty Reduction: An Introduction to Processes, Assessment and Options*. ERD Working Paper Series No. 2. Manila: ADB.

Clarke, R. and A. Low. 1993. "Risk Analysis in Project Planning: A Simple Spreadsheet Application using Monte Carlo Techniques." *Project Appraisal*. Volume 8 Number 3: 141-6. September 1993.

Dinal, A., T.K. Balakrishnan and J. Wambia. 1997. "Political Economy and Political Risks of Institutional Reforms in the Water Sector." World Bank Working Paper (draft), Washington DC: World Bank.

European Commission. 1997. *Financial and Economic Evaluation of Development Projects*.

Fujimura, M. and J. Weiss. 2000. *Integration of Poverty Impact In Project Economic Analysis: Issues in Theory and Practice*. EDRC Methodology Series No. 2. October 2000. Manila: ADB.

Harberger, A. 1998. "Economic Project Evaluation, Part I: Some Lessons from the 1990s." *Canadian Journal of Program Evaluation*. Special Issue: 5–46.

Johnson, K. 1985. *Risk Analysis and Project Selection: A Review of Practical Issues*. ADB Economics Staff Paper No. 28. Manila: ADB.

Little, I.M.D., and J. A. Mirrlees. 1974. "Risk, Uncertainty and Profit." In *Project Appraisal and Planning for Developing Countries*. London: Heinemann.

Mariano, C. 2001. *Risk Analysis Software Packages Evaluation Report*. Unpublished report under RETA 5932. Manila: ADB.

Pouliquen, L. 1970. *Risk Analysis in Project Appraisal*. World Bank Staff Occasional Paper No. 11. Baltimore: The Johns Hopkins University Press.

Rayner, N., A. Lagman-Martin, K. Ward. 2002. *Integrating Risk into ADB's Economic Analysis of Projects*. ERD Technical Note No. 2. May 2002. Manila: ADB.

Reutlinger, S. 1970. *Techniques for Project Appraisal under Uncertainty*. World Bank Staff Occasional Paper No. 10. Baltimore: The Johns Hopkins University Press.

Squire, L. and H. van der Tak. 1975. *Economic Analysis of Projects*. Baltimore: The Johns Hopkins University Press.

Swalm, R. 1966. "Utility Theory – Insights into Decision-Taking." *Harvard Business Review*.

UK-DFID. 1997. *Eliminating World Poverty: A Challenge for the 21st Century*. White Paper.

UK-DFID. 2000. *Yunnan Environmental Development Project* (Project Memorandum). London.

UK Overseas Development Agency. 1992 (various editions 1998-1995). *Project Appraisal in Developing Countries: A Guide for Economists*.

UK Treasury Taskforce – Private Finance. 2000. *How to Construct a Public Sector Comparator*. Technical Note Number 5.

World Bank. 2001. *Political Economy and Political Risks of Institutional Reforms in the Water Sector* (draft). Rural Development Department.

World Bank. various. *Staff Appraisal Reports (www.worldbank.org).*