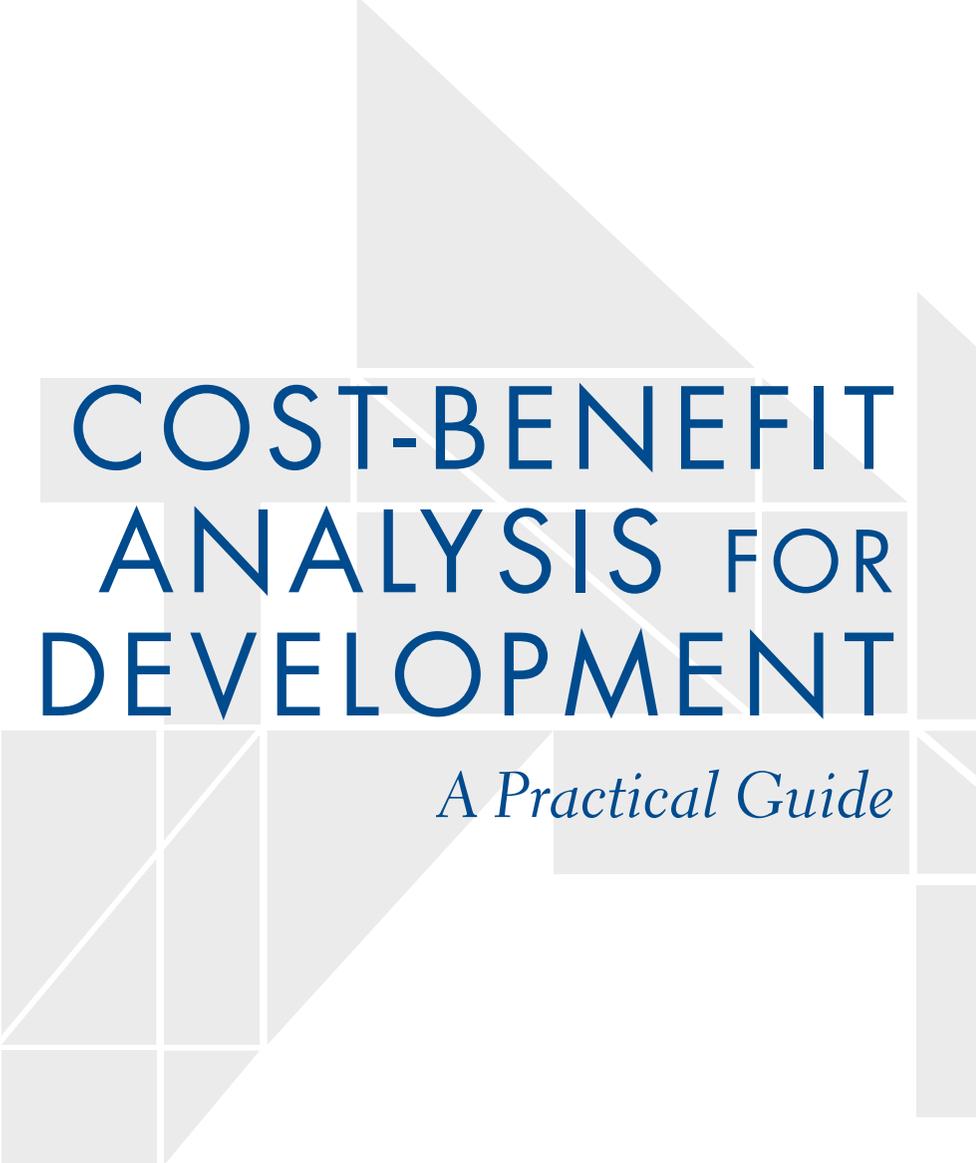


COST-BENEFIT ANALYSIS FOR DEVELOPMENT

A Practical Guide



ADB



COST-BENEFIT
ANALYSIS FOR
DEVELOPMENT

A Practical Guide

Asian Development Bank

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Foreword

Guided by its vision of an Asia and Pacific region free of poverty, Asian Development Bank (ADB) is committed to reducing poverty through increased regional integration and both inclusive and environmentally sustainable growth. With a focus on delivering projects that create positive economic and developmental impact, ADB issued the *Guidelines for the Economic Analysis of Projects* in 1997 to strengthen project quality ‘at entry’. This helps ensure efficient use of development funds, public resources and increases aid effectiveness. The series of economic analysis retrospectives by the Economics and Research Department (ERD) from 2003 to 2008—which assessed the quality of economic analysis applied in ADB operations—paved the way for the updating of specific guidelines on economic analysis. Efforts were focused on improving cost-benefit analysis with an emphasis on key sectors in which ADB operates. This book, *Cost-Benefit Analysis for Development: A Practical Guide*, is the direct result of those efforts.

Intended as a supplement to the *Guidelines for the Economic Analysis of Projects*, this practical guide provides an overview of recent methodological developments in cost-benefit analysis as well as suggested improvements in the economic analysis of selected sectors. Through case studies, this guide also illustrates the application of suggested methodologies, taking into account sector-specific needs, as well as difficulties faced by practitioners in terms of data and time constraints during project processing. Based on actual ADB projects, these case studies focus on infrastructure, particularly integrated urban services (including water supply and sanitation), transport, and power generation and transmission.

This practical guide aims to contribute to building capacity for optimal resource allocation. Its preparation upholds ERD’s mandate of providing operational support toward strengthening project quality-at-entry. It will also be used for in-house training programs on project economic analysis in order to advance the dissemination and diffusion of knowledge on the practical applications of cost-benefit analysis methodologies. The word “development” in this book’s title emphasizes the rigorous use of cost-benefit analysis to ensure that projects are selected and approved based on their potential to use public resources most effectively and, as a result, contribute to development. The word “practical” recognizes the time and resource constraints faced by project analysts in completing a full evaluation. The word “guide” stresses that this book is not intended to be prescriptive, but should be viewed as a source of reference material.

We hope that this guide will contribute to improving operational quality and portfolio performance—an indicator of operational effectiveness under ADB’s results framework, to effectively manage the implementation of Strategy 2020. Although the target audience for this guide is mainly ADB users—project economists, mission leaders, and consultants—as well as their counterparts in ADB’s developing member countries, we hope that it may also serve as useful reference for development practitioners in general.



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This book was prepared and completed with valuable chapter contributions by a team of economists and sector specialists. Herath Gunatilake served as the lead author in preparation of the initial draft. Other contributors include Caroline van den Berg, Franklin de Guzman, Anneli Lagman-Martin, Zhihong Liang, Tun Lin, Viking Logarta, Kee-Yung Nam, Subhrendu Pattanayak, Pradeep Perera, Lilibeth Poot, John Weiss, Jui-Chen Yang, and Juzhong Zhuang. The manuscript was edited by Larson Moth with layout and typesetting by Mike Cortes.

Three chapters of this book are based on previously published materials that include the following: ERD Working Paper No. 94, *Theory and Practice in the Choice of Social Discount Rate for Cost-Benefit Analysis: A Survey*, May 2007; ERD Technical Note No. 19, *Willingness-to-Pay and Design of Water Supply and Sanitation Projects: A Good Practice Case Study*, December 2006; and ERD Technical Note No. 23, *Good Practices for Estimating Reliable Willingness-to-Pay Values in the Water Supply and Sanitation Sector*, December 2007.

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Acronyms and Abbreviations

AADT	annual average daily traffic
ADB	Asian Development Bank
ADL	autoregressive distributed lag
AIC	average incremental cost
CBA	cost-benefit analysis
CEA	cost-effectiveness analysis
CF	conversion factor
CNY	Chinese Yuan
CV	contingent valuation
DALY	disability adjusted life year
DF	demand factor
DICE	Dynamic Integrated Model of Climate and the Economy
DS	divisional secretariats
EB	economic benefit
EGAT	Electricity Generating Authority of Thailand
EIA	environmental impact assessment
EIRR	economic internal rate of return
EPA	Environmental Protection Agency
EPV	economic present value
ERD	Economics and Research Department
EVN	Electricity of Viet Nam
FGD	focus group discussion
FNPV	financial net present value
FPV	financial present value
GDP	gross domestic product
GMS	Greater Mekong Subregion
GN	Grama Niladhari
GNP	gross national product
GOL	Government of Lao PDR
GPS	global positioning system

GT	generated traffic
HDM	Highway Development and Management
HDM-4	Highway Development and Management 4
IPP	independent power producer
IRR	internal rate of return
Lao PDR	Lao People's Democratic Republic
LCA	least-cost analysis
LSMS	Living Standards Measurement Study
LV	low voltage
MCA	multi-criteria analysis
MDB	multilateral development bank
MERALCO	Manila Electric Company
MFF	multitranche financing facility
MV	medium voltage
MWTP	marginal willingness to pay
NOAA	National Oceanic and Atmospheric Administration
NOx	nitrogen oxide
NPR	Nepalese Rupee
NPV	net present value
NT	normal traffic
NT-2	Nam Theun 2
NTPC	Nam Theun 2 Power Company
NWSDB	National Water Supply and Drainage Board
O&M	operating and maintenance
OMB	Office of Management and Budget
PEA	Provincial Electricity Authority
PI	poverty impact
PPA	power purchasing agreement
PPP	public-private partnership
PSDP	Power System Development Plan
PV	present value
RA	risk assessment
RED	Roads Economic Decision Model
RMB	Renminbi
Rs.	Rupees
SBR-CASS	sequencing batch reactor-cyclic activated sludge system

SCC	Southern Coastal Corridor
SCF	standard conversion factor
SDR	social discount rate
SEA	strategic environmental assessment
SER	shadow exchange rate
SERF	shadow exchange rate factor
SO ₂	sulfur dioxide
SOC	social opportunity cost of capital
SPC	shadow price of capital
S RTP	social rate of time preference
SWM	solid waste management
SWRF	shadow wage rate factor
TC	travel cost
TERI	Tata Energy Research Institute
THH	Theun Hinboun Hydropower
T/L	transmission line
TV	terminal value
UCT	University of Cape Town
UV	ultraviolet
VND	Vietnamese Dong
VOC	vehicle operating cost
WSS	water supply and sanitation
WTP	willingness to pay
WWTP	wastewater treatment plant

MEASURES

GWh	gigawatt-hour
km	kilometer
km ²	square kilometer
kV	kilovolt
kW	kilowatt
kWh	kilowatt-hour
m	meter
m ²	square meter
m ³	cubic meter
mm	millimeter
MW	megawatt
TWh	terawatt-hour

1. Introduction

1.1 Rationale

The Asian Development Bank (ADB)'s *Guidelines for the Economic Analysis of Projects*, issued in 1997, aims to enhance project quality at entry. Promoting rigorous economic analysis helps ensure that ADB finances projects and programs that are not only economically viable, but also represent the most efficient use of scarce resources. As such, rigorous economic analysis contributes significantly to enhanced operational quality and portfolio performance—one of the indicators of operational effectiveness under ADB's results framework to manage the implementation of Strategy 2020¹—as well as to further development effectiveness.

The guidelines issued in 1997 outline the economic principles underpinning the suggested methodologies for project economic analysis in ADB and provide illustrations of their application. They are supplemented by sector-specific guidelines, technical notes, and other reference materials produced by the Economics and Research Department (ERD) to assist project economic analysis in ADB (see Appendix to this Chapter).

Through a series of annual retrospectives from 2003 to 2008, ERD reviewed the quality of economic analysis in ADB and noted significant scope for improvement, particularly in the articulation of the projects' economic rationale, demand analysis, and alternatives analysis. The 2007 retrospective indicates significant variations in the quality of project economic analysis across sectors.² On average, energy projects show relatively better quality in their economic analyses, followed by

¹ ADB. 2008. Long-Term Strategic Framework of the Asian Development Bank. Manila.

² ADB. 2007. Economic Analysis Retrospective 2007: Strengthening the Quality of Economic Analysis in ADB Operations. Manila.

transport, water supply and sanitation, while agriculture and natural resources projects have the greatest need for improvement.

This book, *Cost-Benefit Analysis for Development: A Practical Guide*, is written in response to the retrospectives' findings with an aim to supporting ADB's strategic priorities. This book includes extensive and detailed case studies focusing on infrastructure, comprising integrated urban services (including water supply and sanitation), transport, power generation and transmission. These case studies present economic analyses of relatively better quality than those done in other sectors, although there is still room for improvement. By further enhancing the quality of infrastructure projects—one of ADB's five core areas of operation—this guide directly contributes to the implementation of Strategy 2020.³

1.2 Organization of this Book

Subsequent to this introductory chapter, the evolution of cost-benefit analysis together with its current use is discussed in Chapter 2. Changing economic policy environments inevitably influence the methodology and practice in cost-benefit analysis. In this chapter, some of the recent methodological developments will be highlighted as they address weaknesses of the original methodology. The chapter also reviews the current practice of cost-benefit analysis by international donor agencies or national governments to establish the relevance of cost-benefit analysis in contemporary development efforts.

Chapter 3 discusses the theoretical foundations for the choice of the social discount rate (SDR), which is critical in project economic analysis. It provides a survey of the vast literature on the SDR, covering theory, estimation methods, and policy practices. The survey reveals significant variations in public discount rate policies, with developing countries in general applying higher SDR rates (8%–15%) than developed countries (3%–7%). While these variations reflect the different analytical approaches used, the divergence more importantly reflects the differences in the perceived social opportunity cost of public funds across countries, and in the extent to which intergenerational equity is taken into consideration in setting the SDR.

³ Future volumes of this guide will focus on other sectors.

The remainder of the book is devoted to sector-specific guidelines, examples, and case studies. Each case study covers the entire spectrum of the analysis—macroeconomic and sector context, economic rationale, demand, alternatives/least-cost, cost-benefit, sensitivity, risk, and distribution. Meant for illustration purposes, the depth of the presentation varies across sectors to highlight particular aspects of the analysis where minor improvements can be effected to enhance the quality of the economic analysis.

Chapter 4 outlines good practices in conducting willingness-to-pay (WTP) surveys in the water supply and sanitation sector (WSS). Reliable estimates of WTP constitute the basis for assessing effective demand and the benefits of WSS service improvements. The chapter argues that oftentimes, WTP data gathered in many project preparatory studies are rarely utilized for such detailed analyses. Also, poorly designed and implemented WTP studies, especially in developing countries, may provide misleading information on project feasibility and sustainability. The chapter aims to provide a set of guidelines for conducting contingent valuation (CV) studies in the WSS sector. It covers preparations in planning a CV study, study design (sampling strategy, contingent market scenarios, and the survey instrument), survey implementation, data management and validation, and utilization of results for the analysis of effective demand and other policy-relevant issues.

To showcase good practice in action, Chapter 5 assesses the WTP for water in Sri Lanka. It illustrates how good practices discussed in Chapter 4 were employed in conducting a CV study for assessing demand and designing tariffs for improved water services. The chapter also shows how the results of the study were used to facilitate the design of a public-private partnership to provide WSS services in two areas in the southwest. The chapter describes the preparatory work undertaken for the CV study, presents study design issues focusing on the measures taken to reduce potential biases, and discusses how the CV study was administered and implemented. It also illustrates how supplementary survey information is used to evaluate households' effective demand for improved service, preference for the institutional provider, the feasibility of a spatially based pro-poor service delivery, affordability to the poor, and acceptability of the improved service under scenarios of different connection charges and different tariff and subsidy options to design appropriate pro-poor services.

Chapter 6 details the economic analysis of integrated urban services projects, elaborates on the application of techniques discussed in Chapters 4 and 5, and presents a case study on an integrated urban services project.⁴ The chapter argues that the multi-sector nature of urban development projects requires a higher level of effort in and greater resources for economic analysis as compared to projects involving only one sector. It outlines the concepts and approaches to benefit estimation for different types of urban services specifically: district heating, solid waste management, wastewater treatment, and water supply. Focus is on the benefit transfer method, which uses data from a pre-existing analysis of the sector or from an analysis undertaken for a similar project in a different location. The chapter also provides an example of the use of hedonic pricing related to urban improvements that raise property values. The case study enriches the discussion on the cost-benefit analysis for the entire project of a multi-sector nature, on top of the analysis of the individual components.

Chapter 7 reviews the approach to the economic analysis of transport projects. Transport projects can be highly complex in nature due to their broad inter-relations with all other sectors of the economy. The chapter argues that attention should be devoted to demand forecasting, which is arguably rather crude in practice. Forecast traffic flows are often simplistically based on an extrapolation of past trends or on an assumed income elasticity of demand, linking forecast growth in gross domestic product with traffic. The chapter notes that one of the major weaknesses of demand forecasting in the current practice of transport project evaluation is the exclusion of the price effects on demand.

Another focus in this chapter is on road projects and provision of a detailed illustration of how to conduct a road appraisal. This shows how relatively simple improvements can be applied to increase the analytical rigor of the standard approach to appraisals. In terms of the methodology, the case study extends standard practice in ADB appraisals in several ways: (i) by incorporating a price effect in traffic forecasts; (ii) by including a separate estimate of developmental benefits based on future traffic; (iii) by presenting differential treatment of work and leisure time; (iv) by including passenger as well as vehicle operator time savings and incorporating labor productivity increase in valuing time savings; and (v) by incorporating a terminal value in assessing the economic viability

4 Many of the techniques discussed in Chapter 5 are also applicable to rural development projects which are also multi-sector in nature.

of the project. The case study also includes the use of a software program to undertake risk analysis.

Chapter 8 illustrates key features of the economic analysis of power sector projects, focusing on the methodology for benefit valuation. It notes that the methodology for the economic analysis of power projects has not undergone major changes since the late 1980s. Benefit estimation, in particular the WTP for incremental energy consumption, continues to rely on simple approximations. Use of demand information generated from econometric techniques in assessing benefits has been rare despite increased availability of demand functions for electricity in developing countries. Using a simple demand-supply framework, the chapter discusses the methods of estimating benefits for two categories of power generation—serving new markets and reduction in power shortages—as well as of power projects built to reduce generation costs by displacing or rehabilitating old facilities, and to improve system reliability.

In estimating benefits of power transmission projects, the chapter distinguishes between a power transmission project which is part of the entire power system and where all aspects are interrelated and transmission cannot function in isolation; and a power transmission project which can be evaluated as a stand-alone project. Examples of the latter include the rehabilitation or replacement of an old transmission line in which the benefits of reduced transmission losses can be directly attributable to the project, and a transmission project which is a discrete component of an expansion plan and the power transmitted by the project can be identified as displacing a particular set of alternative power suppliers in a given area. The chapter also presents a brief discussion of methods for demand forecasting such as trend analysis, end-use models and customer surveys, and econometric methods.

Finally, Chapter 9 presents two case studies—power generation and power transmission—which apply the methods described in Chapter 8. Both pay attention to demand and least-cost analysis, and also perform distribution and risk analysis. The power generation project is a regional project that creates gains for more than one participating economy, whereas the power transmission project is about how to design a power investment program. The former case study discusses the distribution of benefits between participating countries in the region while the latter illustrates the estimation of benefits by distinguishing those that accrue to new residential consumers, existing residential consumers, and non-

residential consumers. The latter also approximates consumer and producer surplus, and assesses how net benefits are distributed among stakeholders.

Appendix 1.1

Economic Analysis-Related Publications by the Asian Development Bank

- ADB. 1997. *Guidelines for the Economic Analysis of Projects*. Manila.
- _____. 1997. *Guidelines for the Economic Analysis of Telecommunications Projects*. Manila.
- _____. 1998. *Guidelines for the Economic Analysis of Water Supply Projects*. Manila.
- _____. 1999. *Handbook for the Economic Analysis of Water Supply Projects*. Manila.
- _____. 2000. *Handbook for the Economic Analysis of Health Sector Projects*. Manila.
- _____. 2001. *Integrating Poverty Impact Assessment in the Economic Analysis of Projects*. Manila.
- _____. 2002. *Integrating Risk Analysis in the Economic Analysis of Projects*. Manila.
- _____. 2003. *Economic Analysis of Policy-based Operations: Key Dimensions*. Manila.
- _____. 2003. *Economic Analysis in 2002: A Retrospective*. Manila.
- _____. 2004. *Key Areas of Economic Analysis of Projects: An Overview*. Manila.
- _____. 2004. *Economic Analysis Retrospective: 2003 Update*. Manila.
- _____. 2005. *Economic Analysis Retrospective 2004: Sector Diagnosis in Education*. Manila.
- _____. 2006. *Economic Analysis Retrospective 2005: Strengthening Quality-at-Entry of ADB Operations*. Manila.
- _____. 2007. *Economic Analysis Retrospective 2006: Improving the Diagnostic Quality of Economic, Thematic, and Sector Work Underpinning Country Partnership Strategies*. Manila.
- _____. 2008. *Economic Analysis Retrospective 2007: Strengthening the Quality of Project Economic Analysis in ADB Operations*. Manila.

- Adhikari, R., P. Gertler, A. Lagman. 1999. *Economic Analysis of Health Sector Projects: A Review of Issues, Methods, and Approaches*. Economic Staff Paper No. 58. ADB, Manila.
- Ali, I. 1989. *A Review of the Economic Analysis of Power Projects in Asia and Identification of Areas of Improvement*. EDRC Report Series No. 45. ADB, Manila.
- _____. 1989. *A Framework for Evaluating the Economic Benefits of Power Projects*. Economic Staff Paper No. 43.
- _____. 1990. *Issues in Assessing the Impact of Project and Sector Adjustment Lending*. EDRC Report Series No. 53. ADB, Manila.
- _____. 1991. *Economic Analysis of Investment in Power Systems*. Economic Staff Paper No. 49. ADB, Manila.
- Bloom, E. and P. Choynowski. 2003. *Economic Analysis of Health Projects: A Case Study in Cambodia*. Technical Note No. 6. ADB, Manila.
- Bolt, R. 2005. *Improving the Relevance and Feasibility of Agriculture and Rural Development Operational Designs: How Economic Analyses Can Help*. Technical Note No. 12. ADB, Manila.
- Bolt, R. and M. Fujimura. 2002. *Policy-based Lending and Poverty Reduction: An Overview of Processes, Assessments, and Options*. ERD Working Paper No. 2. ADB, Manila.
- Desai, N. 1985. *Economic Analysis of Power Projects*. Economic Staff Paper No. 24. ADB, Manila.
- Dixon, J. A., R. A. Carpenter, L. A. Fallon, P. B. Sherman, and S. Manipomoke. 1986. *Economic Analysis of the Environmental Impacts of Development Projects*. Economic Staff Paper No. 31. ADB, Manila.
- Dole, D. 2002. *Economic Issues in the Design and Analysis of a Wastewater Treatment Project*. Technical Note No. 4. ADB, Manila.
- Johnson, J. K. 1985. *Risk Analysis and Project Selection: A Review of Practical Issues*. Economic Staff Paper No. 28. ADB, Manila.
- Lagman-Martin, A. 2004. *Shadow Exchange Rates for Project Economic Analysis: Toward Improving Practice at the Asian Development Bank*. Technical Note No. 11. ADB, Manila.
- Lin, T. and F. De Guzman. 2007. *Tourism for Pro-Poor and Sustainable Growth: Economic Analysis of ADB Tourism Projects*. Technical Note No. 20. ADB, Manila.
- Rayner, N., A. Lagman-Martin, and K. Ward. 2002. *Integrating Risk into ADB's Economic Analysis of Projects*. Technical Note No. 2. ADB, Manila.

- Tadle, A. M. 1990. *Evaluation of Water Supply Projects: An Economic Framework*. EDRC Report Series No. 51. ADB, Manila.
- Ward, K. 2003. *Strengthening the Economic Analysis of Natural Resource Management Projects*. Technical Note No. 7. ADB, Manila.

2. Economic Analysis of Projects: An Overview

2.1 Introduction

The starting point for project economic analysis (or cost-benefit analysis [CBA]) is that a financial perspective alone will not capture the gains to society at large and that a quantitative assessment of economic costs and benefits is necessary.¹ Financial appraisals of projects are of particular importance because they reveal the adequacy of financial incentives for project beneficiaries to participate in the project, and the degree to which financial resources will be deployed over the project's life span to ensure financial sustainability. However, financial measures can be highly misleading as indicators of the social welfare improvements of a project. This is because key outputs from many projects are either not sold on a market (for example, non-toll roads, solid waste management, reduction in air and water pollution, health improvements from water supply and sanitation) or are sold in distorted or controlled markets (for example, water and electricity sales subject to administrative pricing). Furthermore, even where project outputs are sold at commercial or market-clearing prices, for large projects with price effects, the benefits in terms of social welfare improvements differ from project revenues.

This chapter aims to survey some of the key issues relating to the application of project economic analysis to highlight some recent methodological developments and to review its relevance to the current practice of governments and donor agencies.

Project economic analysis is an analytical framework for converting the costs and benefits of a project to comparable monetary units, so they can be compared systematically and incorporated in a measure of

¹ The terms project economic analysis and CBA are used interchangeably in this chapter.

project worth. It originated in the analysis of water resource projects in the United States in the 1930s and as discussed below, retains its relevance in the context of higher income economies. However, CBA as it applies in a development context, which is the focus of this volume, emerged in the late 1960s and early 1970s with the seminal works of the literature (Little and Mirrlees 1969, 1974; UNIDO 1972; Squire and van der Tak 1975).² The close timing of the various contributions was not accidental. Aid flows, which were then largely project-based, had become quantitatively significant, but in the era of what were perceived as widespread policy distortions, there were doubts concerning the effectiveness of conventional financial appraisal techniques in assessing the full economic impacts of projects.

Today, the primary focus of economic analysis of projects resides in the infrastructure field. However, as explained in this chapter, in spite of the reduced degree of macro policy distortions in most countries, CBA retains its relevance for decision making based on the efficient allocation of public resources. Macroeconomic distortions are only one justification for CBA, even though much attention was paid to them initially. More broadly, “market failure” provides the fundamental reason for undertaking CBA. The divergence created between private and social costs and benefits due to market failures results in prices that do not reveal marginal social costs or benefits. Thus, financial analysis undertaken with such prices is inadequate as a means of judging the efficiency of resource allocation.

Because of the divergence between private and social costs and benefits, governments intervene in the economy and CBA provides a key tool for assessing whether such intervention will improve social welfare. It aims to ensure that projects contribute to net social welfare and that if there are any ‘losers’ from a project, aggregate benefits (as reflected in a positive net present value) are large enough for gainers to potentially compensate any losers.³ However, donor agencies and governments sometimes go beyond this requirement. In particular the environmental and social safeguard policies of donors have made it a requirement to compensate for certain types of easily identifiable losers of projects. Compensation for involuntary resettlement is a clear example of actual compensation payments.

² Surveys of this methodology are found in Irvin (1978), Ward and Deren (1991), Perkins (1994), Dinwiddie and Teal (1995), Curry and Weiss (1990 and 2000), Potts (2002), and Londero (2003).

³ This stems from the Kaldor-Hicks potential compensation criterion.

2.2 Original Methodology and Changing Policy Environment

The early literature on CBA was ambitious in the sense that it aimed to assess projects not just from the allocative efficiency viewpoint, but also in terms of their contribution to growth (through higher savings and reinvested income) and redistribution (through higher income for poorer groups). If an analysis is to capture diverse effects, this requires such effects be converted into a common unit of account or numeraire. Thus, the diverse effects on short-run resource allocation, growth, and redistribution need to be weighted and combined in a single measure. *Little and Mirrlees (1969 and 1974) and United Nations Industrial Development Organization (UNIDO) (1972) proposed different approaches to achieve this objective. The former used the world price numeraire, in which domestic prices are converted to world prices by using the standard conversion factor (SCF). The latter used the domestic price numeraire, in which world prices are converted to domestic prices using the shadow exchange rate (SER).*

In practice, simplified versions of the original Little-Mirrlees and UNIDO approaches have been applied (dropping the savings premium and the use of distribution weights), so the difference is reduced to one of price unit, since whenever there is trade protection, domestic prices will, on average, differ from world prices. This distinction retains practical relevance as agencies like Asian Development Bank (ADB) and the World Bank do not utilize a consistent application of one form of price numeraire. While the world price/ local currency unit tended to dominate practice in the 1970s and 1980s—for example, the World Bank publication by Squire and van der Tak (1975) used world prices, as did the British government publication Overseas Development Agency (ODA) (1988)—more recently, some disadvantages associated with its use have become apparent. ADB (1997) stressed that the use of the domestic price numeraire has a distinct advantage in conducting distribution analysis. Although up to its publication, a majority of ADB appraisals had used the world price numeraire. Incidentally, the choice of price numeraire however, does not affect the results, since both give the same economic internal rate of return.

The original literature of the 1960s and 1970s was primarily concerned with an assessment of the efficiency of projects in tradable sectors,

principally industry and agriculture, where aid financing was important at the time. In the era of import substitution in many countries, there was strong evidence that many projects were only financially viable because of the shelter granted by trade protection. The Little-Mirrlees framework was much more systematic than earlier practice and focused on what were perceived as three key important aspects of developing economies like India: shortage of foreign exchange; shortage of savings; and labor surplus in rural areas. The policy interventions that were judged to have worsened the situation created what were deemed “distorted economies”. However, the key aspect of the literature of this period stated that these distortions (like trade barriers, fixed exchange rates, and interest rate ceilings) were taken as a given part of the policy landscape, which project analysts could do little to influence. This meant that the valuation system would be based on “second-best” economic prices in the continued presence of policy controls over markets.

The Little-Mirrlees methodology responded to this “heavily distorted economies” scenario with the simple step of using the world price as the economic price of an internationally traded good. By using world prices as the measure of value for goods that are tradable on the world market, the distortionary impact of protection can be removed and projects can be assessed in terms of trade efficiency criteria. This idea was initially misunderstood, with some arguing that it implied that world prices were a measure of undistorted value because they were taken to be perfectly competitive while domestic prices were in fact, distorted. As the authors clarified subsequently, the use of world prices is due to the fact that they represent the terms on which an economy can participate in world trade (not any notion of their competitive nature) and their use to value inputs and outputs is to allow projects to be planned in line with comparative advantage.

Since one of the prime motivations of the original project economic analysis methodology was to strip away the effects of macro distortions on project decision making, the literature devoted considerable attention to ways of empirically estimating “true” economic prices for such parameters. These parameters were estimated initially using relatively simple partial techniques, which did not take into account feedback effects on the economy. Macro shadow prices for labor, capital, and foreign exchange were estimated for a number of economies using approaches of varying degrees of sophistication. The most common macro conversion factors (CFs) were for unskilled labor (the average ratio

of the shadow to the market wage) relevant for labor surplus economies, and the foreign exchange factor (the ratio of the shadow to the official exchange rate or its inverse, the SCF) relevant for economies with trade taxes and disequilibrium exchange rates.⁴ The shadow exchange rate (SER) premium was often approximated by the average rate of tax and subsidy on foreign trade.⁵ An average shadow wage rate factor (SWRF) was often based on a rough estimate of output foregone in agriculture relative to wages paid by new projects. In a competitive economy with a fully flexible labor market, migration would equate the two, but barriers to migration and controls such as minimum wage legislation (where it is enforced) can work to keep project wages above the opportunity cost of labor.

A major breakthrough in the consistent estimation of a national set of macro CFs (also termed national economic parameters) came in the late 1970s with the development of the semi-input-output method.⁶ This approach used input-output techniques to trace through the direct and indirect factor content of different sectors. A set of primary factor inputs were identified—typically traded goods, skilled and unskilled labor, non-traded goods that could not be decomposed further, and transfers such as taxes and subsidies. Primary inputs were either given values determined exogenously or were valued endogenously within the model. Thus, the economic price of any sector j (EP_j) would be determined by a weighted average of the conversion factors of primary inputs x into j thus:

$$EP_j = \sum ax_j * CF_x \quad (1)$$

$$CF_j = EP_j / FP_j \quad (2)$$

where ax_j is the value of primary input x into sector j , FP_j is the financial price value of j and summation is for all x . This approach has the disadvantage of any input-output system in employing fixed coefficients

⁴ A simple device for moving between financial and economic appraisals was the estimation of conversion factors which are ratios of economic to financial prices. If financial price data can be disaggregated into appropriate categories (as illustrated in the case study chapters of the book), once conversion factors are estimated for each category then multiplication of the financial data by the relevant conversion factor gives a set of economic prices.

⁵ For early estimates, see Beyer (1975) for an illustration of various approaches to estimating the shadow exchange rate for India. Lal (1980) provides a set of comprehensive CF estimates for India. UNIDO (1980) and Weiss (1979) give estimates for Pakistan.

⁶ The early work was done by Maurice Scott in Scott et al. (1978) for Kenya and followed up for several countries in Latin America in Powers (1981) and Londero (2003). Weiss (1988) provides a simple illustration of the method. Unpublished studies using this approach were carried out at Bradford University, UK for a number of countries including the People's Republic of China, Ethiopia, Jamaica, Latvia, Lithuania, Malaysia, and Sri Lanka; see also Saerbeck (1989) for Botswana.

but it has the advantages of both picking up indirect effects (for example, not just the direct employment effects but also indirect backward linkage employment effects from the expansion of production of non-traded inputs used by a project) and of providing consistency.

While estimating shadow prices in project work was seen as critical in the early days of CBA, it is now much less important, and semi-input-output studies of the type discussed are now rarely conducted. The difference is that during the 1980s and 1990s many of the policy constraints identified in the 1970s were removed, for example; the introduction of flexible exchange rates, the lowering of trade barriers, the decontrol of interest rates, and the unwillingness to enforce minimum wage legislation. Moves toward price decontrol in key infrastructure sectors to meet financial obligations also helped reduce the gap between economic and financial prices.

In this policy environment, the gap between financial and economic prices was reduced, but not removed entirely due to some remaining taxes and subsidies, and other distortions. The labor surplus scenario in particular remains relevant in many low-income countries, where markets for unskilled labor fail to clear by bidding down wages to remove unskilled unemployment. It is still not uncommon to see unskilled labor CFs of 0.5, for example, applied in low-income countries like Cambodia or Lao People's Democratic Republic. In addition, although it is not often recognized in practice, market-determined short-run prices may not reflect true economic value over the life of a project. The most obvious illustration of this relates to the foreign exchange market. A short-run exchange rate determined in a foreign exchange market driven by speculative or temporary capital flows does not necessarily reflect the long-run worth of foreign exchange and it is this latter value that is needed in an economic appraisal of a project. Hence, although long-run values for foreign exchange are rarely estimated—with short-run values typically used as their proxy—this further adjustment (through a change in the shadow exchange rate in future years) is required for accuracy.⁷

Of the constraints identified in both the UNIDO and Little-Mirrlees approaches, the savings shortage has been largely ignored. This was for both pragmatic and policy-related reasons. In practical terms, there is considerable uncertainty in the estimate of a savings premium, since it

⁷ Theoretically, the shadow exchange rate (SER) premium has two components: (i) the deviation of the long-run real exchange rate from its current value, and (ii) the price effect of tariffs and controls on trade. The two are interrelated but both should be projected over the life of a project (Londero 1996).

depends on the marginal productivity of capital, the reinvestment rate out of project income, and the time preference rate of discount. In policy terms, it can also be argued that project level decisions are not the most effective way of raising savings, and that financial sector reform that expands the opportunity for financial savings, while decontrolling interest rates, offers the best way of addressing the problem. This does not avoid the issue of scarcity of government income, which needs to be addressed separately, primarily through fiscal measures.

The issue of placing a premium value on government income was identified in Little and Mirrlees and was set out clearly in Squire and van der Tak (1975). The latter defined the value of government income as the returns on additional government investment foregone. This approach assumed that at the margin, additional government income would be invested. This is only one possibility. An alternative assumption, used in some later estimates, was to treat government income as fixed so that additional income generated (used) by a project led to a fall (rise) in taxation. Here, the value of government income will be determined by the cost of raising taxation in the least distortionary means possible (Devarajan et al. 1996). While the savings premium was rarely applied in empirical work, there have been attempts to estimate this latter alternative approach to government income, although most estimates were for developed economies.⁸

The original methodology thus changed in line with shifts in policy. In particular, due to macro reforms, the emphasis on shadow pricing was reduced and the assessment of a projects' growth contribution through higher savings and reinvested income was no longer pursued to a significant degree.

2.3 Methodological Developments

The original methodology of economic analysis has been extended in a number of ways in recent decades. This section focuses on several of these:

- (i) Income distribution and poverty
- (ii) Risk and uncertainty

⁸ See for example the estimates in Browning (1987); Ahmad and Stern (1987) give detailed estimates for India.

- (iii) Valuation of non-marketed goods
- (iv) Environmental sustainability
- (v) Discounting⁹

2.3.1 Income Distribution and Poverty

Attitudes toward the incorporation of distributional and poverty reduction objectives in project decision making have changed over time with shifts in aid fashion. The original methodology was developed and applied initially in the 1970s during the World Bank Presidency of Robert McNamara, with poverty reduction as the main focus of development assistance. However, during the 1980s this focus became diluted, with the emphasis turning to macroeconomic reforms and debt rescheduling. It reappeared again in the late 1990s partly as a result of the perceived neglect of the poor during the Structural Adjustment era and with the persistence of large pockets of poverty in many countries, despite years of development aid. However, as discussed below, this has been an area of controversy and in practice systematic weighting of project outcomes has rarely been carried out.

Both Little and Mirrlees (particularly their 1974 book) and UNIDO (1972) recommended the use of a weighting system to distinguish between benefits to the rich and those to the poor, with the latter being weighted at more than unity and the former at less than unity. This approach was set out more formally in Squire and van der Tak (1975) who showed how distributional weights could feed into a variety of parameters.¹⁰ Initially, the principal focus was on an adjustment to the shadow wage on the grounds that the main increase in consumption created by a project would be through payment to unskilled workers in excess of their opportunity cost. Since the labor surplus argument was applied, it was assumed that the gap between formal sector wages paid by a project and their alternative marginal product would be high and that this extra income would be consumed. The main application of distributional weights in both Little and Mirrlees (1974) and Squire and van der Tak (1975) was therefore through the economic price of labor.

⁹ Discussed separately in Chapter 3.

¹⁰ Ray (1984) explained much of the underlying welfare theory and formalized many of the expressions in Squire and van der Tak (1975).

This procedure of introducing weights into the economic price of labor has been highly controversial and complex, with many adjustments introduced in a single equation. The most important shortcoming is the lack of objectivity in selecting the elasticity that reflects the declining social worth of an extra income as the consumption level of the project beneficiaries rises.¹¹ The approach utilizing differential weights is only partial because any project will have distributional effects that go beyond just the extra income going to unskilled workers, for example, with gains to consumers, investors, and governments. A comprehensive analysis requires disaggregating the net income change created by a project—its economic net present value (NPV)—into changes for different groups. These income changes can then be decomposed into changes in consumption and savings and, if necessary, different weights can be applied to these. Thus, for a project involving four groups of stakeholders, for example A (workers), B (consumers), C (investors), and D (government):

$$\text{Economic NPV} = PV_A + PV_B + PV_C + PV_D \quad (3)$$

where PV is the present value of income and subscripts refer to the four groups. The savings and consumption components of these income changes can be identified given the marginal propensity to save (s) for each group. Thus, the present value of the total change in savings (PVS) will be:

$$\text{PVS} = s_A * PV_A + s_B * PV_B + s_C * PV_C + s_D * PV_D \quad (4)$$

where s_A , s_B , s_C and s_D are the marginal propensities to save of the four groups. Similarly, the present value of the total change in consumption (PVC) will be

$$\text{PVC} = (1-s_A) * PV_A + (1-s_B) * PV_B + (1-s_C) * PV_C + (1-s_D) * PV_D \quad (5)$$

Once all income changes created by a project are disaggregated in this manner, weights can be applied to each component and the sum will give a new weighted economic NPV.

This comprehensive approach to distribution was set out originally in UNIDO (1972) and applied with distributional weights in UNIDO (1980), which was one of the rare attempts to conduct a comprehensive distribution-weighted appraisal. Without the use of weights, it forms the

¹¹ Attempts were made to infer a value for this elasticity from the degree of progressiveness in the tax system, but this approach is flawed because if taxation were optimally designed to meet distributional objectives there would be no need to use a weighting system in the first place.

basis of current attempts to trace through the full distributional effects of projects (see the discussion in Chapter 9, for example). However, the use of weights to differentiate the social worth of benefits going to, or costs borne by, different income or social groups has not been adopted in any significant operational way. The World Bank, which undertook the initial research and published the Squire and van der Tak book, experimented with the use of weights in some research, but ruled out incorporating them in operational work by the early 1980s (Devarajan et al. 1996).

There were several reasons why the widely publicized and much debated distributional weighting scheme faltered. First, was its complexity, with project teams finding it difficult in practice to trace through the set of income changes created by a project. Second, given the subjective nature of the weight there existed a serious risk of inconsistency across countries or sectors which could distort decisions. Third, some questioned the welfare basis of a weighting system relying on subjective elasticity values.¹² Lastly, and most fundamentally, it was argued that project selection was a very ineffective means of influencing the distribution of income and that fiscal policy and the allocation of public sector expenditure are much more effective means of addressing distributional issues. Hence, despite the existence of a widely cited early literature, the use of distributional weights was never formally applied by international agencies or national governments.

The revived focus on poverty reduction at the end of the 1990s saw the method of distribution analysis, as laid out in UNIDO (1972), applied in a number of studies, but without the application of weights.¹³ In tracing through the gains and losses to different groups, this analysis draws on the identity:

$$\text{Economic NPV} = \text{Financial NPV} + (\text{Economic NPV} - \text{Financial NPV}) \quad (6)$$

This indicates that there are two sets of income flows created by a project: those arising from its financial effects (for example, profits, subsidies, and taxes), and those generated by the difference between economic and financial prices (for example, between the shadow wage and the wage actually paid, and between the shadow exchange rate and

¹² Harberger (1978), for example, argued that the weighting scheme gave implausibly high weights to some groups and implausibly low ones to others. There are still some like Brent (2006) who have argued consistently that equal weighting for all is also subjective and that there is a strong theoretical case for some form of weighting.

¹³ For research-based applications, see the very detailed work of Londero (1996).

the market exchange rate).¹⁴ Simply using the same data as in a basic economic analysis, it is possible in principle to trace through the income effects for different groups. (The mechanics of doing this are illustrated in Chapter 9).

Disaggregating income changes for different stakeholder groups in an unweighted form is potentially very useful. It allows an assessment of whether the return to investors is sufficient for a project to be financially sustainable. By estimating the change in government income, it allows an assessment of the fiscal impact of a project. It allows an estimate of how the poor are affected by a project and thus the extent to which a project helps achieve the objective of poverty reduction.

Poverty impact analysis involves estimating the proportion of income going to different groups (such as consumers, workers, or investors) that will accrue to individuals or households who are below the national poverty line. Thus, following the notations used earlier, the poverty impact (PI) will be;

$$PI = p_A * PV_A + p_B * PV_B + p_C * PV_C + p_D * PV_D \quad (7)$$

where p is the proportion of income going to the poor. PI can be presented as either an absolute value or as share of the total net benefits of the project, so the poverty impact ratio (PIR) is

$$PIR = PI / \text{Economic NPV} \quad (8)$$

This approach is recommended in ADB (1997) and Belli et al. (2001). ADB (2001) gives practical guidance on how this might be done. The advantage of this approach is that it avoids the use of weights which are inevitably controversial and although approximate, first-round income changes created by a project can be estimated with no more data than that from the original financial and economic analysis. However, in the absence of further information some of the groups involved may be very aggregate and in some cases the share of income going to the poor may be known only as an approximation.¹⁵ Furthermore, the analysis will

¹⁴ The choice of the price numeraire matters in distribution analysis. By definition, financial NPV will be at domestic prices. However if the economic NPV is at world prices the two sets of income flows will not be directly comparable. It will be necessary either to convert financial flows to world prices (which is potentially confusing) or to calculate the economic NPV using the domestic price numeraire.

¹⁵ In some important sectors the full distributional impact may be very difficult to establish. The benefits from a road project are a good example. Some will accrue to haulers if their costs fall; some will accrue to producers if additional output is induced by the road; some will accrue to consumers if prices are reduced through falling transport costs or extra production; and some will accrue to workers if employment expands. Disentangling these effects will be extremely complex and for many projects would require a major research study.

normally fail to pick up second-round indirect and non-monetary effects, if any. The problem of the indirect dimension is highlighted since there is a need to make an assumption as to how the poor are affected by additional government income, since government income spent on the project would otherwise be spent elsewhere with some poverty impact. To find the true net impact of a project on poverty, this poverty reduction opportunity cost must be taken into account.

Currently, distribution analysis of this type is perceived as critical for two types of projects. Firstly, for projects with targeted interventions for poverty reduction, it is possible to draw up a table of gainers and losers and estimate (even approximately) how many of each group are poor. This is useful in operationalizing, at the project level, widely-stated donor concerns over poverty reduction. Second, distribution analysis is also applied to projects involving more than one country, for example, cross-border roads or power export projects (Adhikari and Weiss 2004). The distribution of net benefits between participating countries is an important aspect of the appraisal of such projects since it sheds light on the fairness and sustainability of cost sharing and pricing arrangements. Hence, for regional cooperation projects, distribution analysis between collaborating countries has become an important part of the appraisals (see Chapter 9).

2.3.2 Risk and Uncertainty

A central feature of project analysis is that any form of *ex ante* appraisal will be projecting an uncertain future. Data on benefits and costs will be entered as single most likely values. The early literature recognized that this is a very crude way of dealing with an uncertain future and that in principle, more formal risk-based approaches are desirable (Pouliquen 1970, Reutlinger 1970). In practice, uncertainty is normally addressed through sensitivity analysis, which identifies key parameters that may affect project outcomes. Sensitivity analysis may be supplemented by the calculation of a switching value for a key parameter.¹⁶ This has always been recognized as being a very approximate means of addressing uncertainty since in reality all parameters will vary. Techniques for addressing

¹⁶ Switching value is the value for a parameter at which the project becomes unacceptable, that is the value at which the economic NPV becomes negative.

this in the form of simultaneous changes in variables in “Monte Carlo” simulations have been known for many years, but it took the widespread use of microcomputers in the early 1990s for them to become part of the toolkit of project analysis. Clarke and Low (1993) and Savvides (1994) showed how this could be done with simple applications, and there are now risk analysis software programs that make the application of risk analysis relatively easy.¹⁷ What is required is to specify which variables are to change simultaneously, their mean value, a plausible range and their variance and distribution around the mean (often taken as a normal distribution). Once the number of simulations is specified, the project outcome is given as a probability distribution.

Risk analysis software packages can run large numbers of simulations, which allow for an expected value estimate for the NPV or internal rate of return (IRR) as the mean of all results from the simulations. This is equivalent to a risk-adjusted indicator of project worth. Another key piece of information that is derived from risk analysis is the probability of an unacceptable outcome (a negative NPV or an IRR below the cut-off rate). Provided that the decision maker is risk-neutral, expected values provide the basis for decision making. Risk neutrality implies that risk of failure can be ignored; for example, where a government or large investor can pool risks across a large number of projects, an unfavorable outcome on one is offset by a favorable outcome on another.¹⁸ Risk neutrality can be accepted as the correct response to risk for all except a particular class of non-marginal or pro-cyclical projects, where failure by one project can affect the whole portfolio.

Expected return and risk are likely to be positively related, since higher return activities are generally more risky. This implies that for large or pro-cyclical projects, the decision criterion for acceptability has two dimensions—expected return and its variance (that is, risk of failure). Project A may have an IRR of 14% (while the minimum acceptable rate is 12%) but a probability of failure of 30%. If the maximum acceptable probability of failure is 25%, then on risk grounds the project should either be redesigned to reduce risk, or rejected. While theory suggests that for a particular class of projects, risk neutrality is not the appropriate way to address risk, as yet in practice a minimum acceptable probability

¹⁷ Belli et al. (2001) recommend this form of analysis for the World Bank; ADB (1997) notes this approach, while Rayner et al. (2002) recommend its use in ADB appraisals, and ADB (2002) gives more detailed guidance on how this could be done.

¹⁸ This is referred to as the Arrow-Lind theorem after Arrow and Lind (1970), who presented the underlying theory.

of failure is rarely incorporated in project decision making. What is an acceptable level of risk is in principle for decision makers themselves to determine, but a rule of thumb can be derived from failure rates on the existing project portfolio as revealed by ex-post evaluation studies.¹⁹

In addition to the use of risk software in project analysis, uncertainty underlies an important theoretical development in the academic literature relating to the “options value” of waiting. The concept originates from the financial literature on “options” or the value of waiting (Dixit and Pindyck 1994).²⁰ There is a clear theoretical case that under uncertainty where a project decision is irreversible, waiting can increase learning and thus more information on likely outcomes will be available to the analyst. Therefore, the value of waiting should be taken into account in project analysis. As many project decisions are in principle irreversible (roads and power plants once built cannot be moved and natural forest land once cleared for development cannot be easily regenerated to its original status), the value of waiting is an important issue and relates to the familiar problem of optimal timing decisions for projects.

Standard project analysis compares expected benefits and costs; however, where irreversibility holds, the option of waiting to see how things develop (for example, if road traffic or power demand grows as predicted) is ruled out, which entails a potential lost benefit. This can be illustrated algebraically for a simple two-period case. Investment K in year 0 generates either high benefits B_A or low benefits B_B with probabilities of p_A and $(1-p_A)$ in year 1. The standard decision criterion is to invest if the economic NPV is positive.

$$\text{Economic NPV} = (p_A * B_A + (1 - p_A) * B_B) / (1 + i) - K \quad (9)$$

where ‘ i ’ is the discount rate, waiting allows K to be invested at i for 1 year, with the option for a decision to be taken 1 year later, only if the higher benefit figure occurs. If the lower benefit figure accrues, the investment need not go ahead. Initial costs K have fallen by waiting as they were invested in year 1 at $i\%$.

Thus with the higher benefit the net present value is;

$$\text{Economic NPV}' = (p_A * B_A) / (1 + i)^2 - K / (1 + i) \quad (10)$$

¹⁹ Weiss (1996) recommends this approach and suggests 25% as a rule of thumb based on past failure rates on World Bank projects.

²⁰ The initial theoretical formulation comes from Arrow and Fisher (1974) in the context of the environment and recent discussions of option value have focused on environmental issues like reaction to global warming (Pearce et al. 2006).

The difference between the two Economic NPV figures (NPV – NPV^o) is the value of the option to wait. Although rarely done, as Dixit and Pindyck (1994) argue in relation to financial appraisal, the value of the option (which can be negative if the future looks worse after waiting) should be treated as part of the opportunity cost of investment funds and added to the initial investment cost of a project under consideration. This should guarantee the correct timing decision since only if the value of waiting is negative, (so the delayed project has a lower NPV than the original one) will the original project be the best choice. Some analyses based on a system approach (such as in the power sector) may incorporate optimal timing concerns; however, project decisions are often still viewed as discrete “yes” or “no” decisions, with relatively little discussion on timing, so that incorporation of this option value can be a useful addition to standard practice.

2.3.3 Valuation Issues

As explained earlier, much of the original literature was concerned with correcting the effect of macro “distortions” on the valuation of costs and benefits often in the appraisal of projects in traded sectors. However, as the aid portfolio has shifted to infrastructure and various social sectors, problems of benefit valuation have had to be addressed.

The development of approaches that value non-marketed outputs, including environmental valuation, has extended the scope for CBA considerably. This book aims to demonstrate the applicability of some of these valuation methods.

Concepts of non-market valuation techniques originated in the 1940s. The proposal of Ciriacy-Wantrup (1947) to use stated preference methods to value natural resources and the environment, in addition to the idea of Hotelling (1949) to use travel costs to value economic benefits of national parks, are the pioneering work on environmental valuation. The literature on environmental valuation has increased significantly, but despite this rise in academic research on the subject, its use in actual project analysis has been limited (Adamowicz 2004).²¹ Broadly speaking, two approaches dominate the applied literature on non-market valuation

²¹ For example, Silva and Pagiola (2003) found that at the time of their survey only about one-third of the relevant World Bank projects used environmental valuation methods, although this was a big rise from 10 years previously.

methods—revealed preference and stated preference approaches.²² Revealed preference studies aim to infer how individuals value a good or service from their observed behavior. In the application for non-market valuation, the non-marketed good or service is valued using a related market.

Revealed preference methods to value non-market goods can be further subdivided into direct revealed preference and indirect revealed preference methods. The direct revealed preference method uses the market price of a good or service that is directly related to the non-market activity. For example, the productivity change method uses the prices of agricultural products to value the cost of soil erosion. Here, the non-market good—soil quality—serves as an input to produce a market good (agricultural produce). The valuation of soil conservation benefits of a forestry or conservation farming project, and benefits of irrigation projects for example, generally use the productivity change method. Similarly, the benefits of mangrove conservation are estimated using incremental change of fishery output.

Indirect methods use surrogate markets to value non-market goods. The hedonic pricing method is a widely used indirect non-market valuation method which assumes that in some markets, environmental factors will influence price and if their independent influence can be identified, this should give an estimate of willingness to pay (WTP) for an improvement in the environmental factor concerned. The approach is used most frequently in relation to property markets, where it is reasonable to assume that air and noise pollution, access to scenic sites and recreational facilities, as well as the location of environmentally hazardous facilities, impact property prices. In development projects, its application is mainly in urban air quality improvement and water supply and sanitation.

The travel cost method is another indirect revealed preference approach. The basic idea is that individuals and their families incur costs in terms of travel in visiting sites of natural beauty and recreation, such as parks or beaches, and that this cost can be used as a means of eliciting what people are willing to pay for these environmental ‘services’, even when no access charges are imposed. Travel cost—defined broadly to include the cost of time—can be used to establish a demand curve for visits to a site of natural beauty where travel cost acts as the price to which

²² See ADB (1996), Champ et al. (2003), Gunatilake (2003), and Freeman (2003) for a detailed description of environmental valuation methods.

demand is related.²³ The travel cost method can be applied considering zones or individuals with repeated visits. A demand curve for recreation is estimated incorporating income and other data that determine visitation rate from a zone (zonal method) or number of visits (individual method). The area under the demand curve gives total WTP, and per person figures must be multiplied by zonal population to give a total WTP per zone. The approach can also be applied where environmental damage affects the attractiveness of visiting a site.²⁴ The hedonic travel cost method assumes that the travel cost is a function of site characteristic (such as pollution level, congestion, etc.) and estimates the demand under different site qualities (Brown and Mendelsohn 1984).

The stated preference method directly elicits people's WTP using survey methods when direct or indirect market information is not available to value non-market goods. This method has two broader categories: contingent valuation and choice experiments. The contingent valuation CV method questions the WTP for a composite commodity whereas the choice experiments unbundle various attributes of the commodity and value each attribute separately. CV studies adopting this approach have been a major growth area for non-market valuation. Water is one of the sectors where this approach was pioneered (Whittington et al. 1991), although it has been applied to value a variety of environmental goods and services including non-use values such as bequest and existence values.

Chapter 4 gives a detailed discussion of the CV method and clear guidance as to how it can be applied in the context of the water supply and sanitation sector. Chapter 5 describes an application of the CV method to water supply and Chapter 6 demonstrates its application for sanitation and solid waste management. The choice experiments method is a recent addition to the toolkit of non-market valuation and the application of which is rapidly increasing in many different sectors.

Health is an area where benefit valuation has proved both difficult and controversial. Health benefits are sometimes divided into avoided mortality and morbidity costs. The averted morbidity effects of an environmental improvement, for example, involve lost wages, averting expenditures (such as expenditure on filtering and boiling water), actual medical expenditures, and disutility of sickness (Freeman 2003). Most

²³ For example, Day (2002) uses a travel cost approach to value game parks in South Africa.

²⁴ Bolt et al. (2005) provide an example of this approach to value the impact of sea pollution on the value placed to visits to the beach outside Davao City, Philippines.

of the estimates exclude the last component and use actual market data to value the first three components. This reduced method is known as a “cost-of-illness” approach. In order to apply this to value the cost of air pollution, for example, the emission should first be converted to concentrations and then a dose–response function used to estimate the increase in deaths and morbidity. This dose–response methodology, where an environmental change (increase in air pollution) is linked with a change in response (number of sick days, number of premature deaths) makes it possible to value the impacts. CV studies on WTP to reduce risk of illness or death is an alternative way to estimate benefits of health improvements.²⁵ CV studies can be used to estimate the total benefits of health improvements, including the cost of disutility.

Mortality costs can be estimated using the “human capital” approach, where the loss of productivity of human beings due to premature death, defined as the present market value of lost earnings, becomes the measure of benefits. This method has a number of shortcomings (Gunatilake 2003) and the alternative statistical value of life method, based on insurance premia is generally preferred to value mortality costs.²⁶ The statistical value of life can also be estimated using the contingent valuation method. For example, Cropper (1992) provides an influential illustration of a revealed preference approach to the valuation of life by focusing on the decisions of the US Environment Planning Agency in restricting the use of pesticides to reduce the risk of cancers; the decision to forego use of pesticides had a cost in lower output which was compared with reduced cancer risk to obtain an implicit value for lower risk.

All attempts to put monetary values on health benefits remain controversial and for that reason there has been frequent use of cost-effectiveness analysis. In the health sector, for example, days of improved health or years of life saved are often used as indicators of project impact with comparison across projects based on a ratio of a health indicator to discounted project costs. For example, detailed work at the World Health Organization in the 1990s developed an influential and widely used set of health indicators, the Disability Adjusted Life Years (DALYs) (Murray 1994, Murray and Lopez 1996). This allowed standard cost-effectiveness comparisons across health projects using discounted costs

²⁵ These studies are surveyed in Pearce et al. (2006, Chapter 14).

²⁶ If, for example, an average WTP to reduce risk of death (from say 5 in 10,000 to 3 in 10,000) is found to be \$50, then the value of a statistical life will be the average figure (\$50) multiplied by the number of individuals affected (10,000) divided by the lives saved (2). Thus, in this instance, the value of a statistical life is $(\$50 \times 10,000) / 2$ or \$250,000.

per discounted DALY as the basis for analysis. ADB (2000) shows in detail how the DALY indicator could be adapted for use in project analysis.

Virtually all studies of this type originated in developed countries and their application is still used in these countries. However, some of the methods are becoming popular among academics in developing countries. In applied work, non-market values estimated elsewhere are borrowed or adapted to developing countries. This method is broadly known as benefit transfer. When applied in a developing country, the initial estimated non-market values are scaled by the difference in income per capita between two countries. This has been recognized as a controversial and unsatisfactory form of benefit transfer because it could result in large errors. A more reasonable approach is to transfer the benefit function estimated in one location in a country to a similar location in the same country or to the same location at a different time. This approach is illustrated in Chapter 6 in the context of urban development projects.

2.3.4 Environment Sustainability

The development of non-market valuation techniques has resolved a number of valuation issues in CBA but the wider application of environmental values in project analysis can be over-ridden by sustainability issues. In principle, if all environmental benefits and costs could be valued accurately and incorporated in an appraisal, a positive economic NPV would indicate that the surplus created by a project would be large enough to compensate any losers. If the project causes environmental damage, having a positive economic NPV means that there would be enough income to make restoration of environmental quality possible. However, there is no guarantee that compensation will either be paid to the communities which experience lower environmental quality or be used to restore ecosystems to their original state.

The idea of a sustainability constraint on project decision taking was designed to address this omission by ensuring that environmental assets are maintained at a minimum acceptable level (Markandya and Pearce 1994). The authors argue that if a critical minimum level of natural (that is, environmental) assets could be specified, and if project investment causes any damage to these assets, a compensating or shadow project

should be introduced to restore the environment to its original state. This so-called “strong sustainability” constraint focuses on one project to offset the damage from a group of projects, on the grounds of economies of scale, and leaves vague practical issues of substitutability between natural assets. It implies that compensation need only be over a future time period, not in individual years. While the argument retains a clear theoretical appeal (Atkinson et al. 2007), in practice at the project level, there is normally an environmental impact assessment to identify the necessary preventive expenditure to avoid the worst form of degradation of environmental assets. Thus, in practice, compensation tends to be project-by-project rather than on a broader program basis, since in many countries the planning system is insufficiently farsighted to identify future projects and their combined environmental effect. Part of the attraction of the original proposal for a sustainability constraint was that by explicitly protecting the environment through a direct constraint, it freed the discount rate to play its normal role of adjusting for time, without a specific environmental concern (see Chapter 3).

2.4 Alternatives to Cost–Benefit Analysis

The above section shows how recent methodological developments have extended the scope for project economic analysis. Nonetheless, efforts have been made to establish operational alternatives to CBA, in part to identify simpler alternatives and to avoid perceived potential for bias and manipulation.²⁷

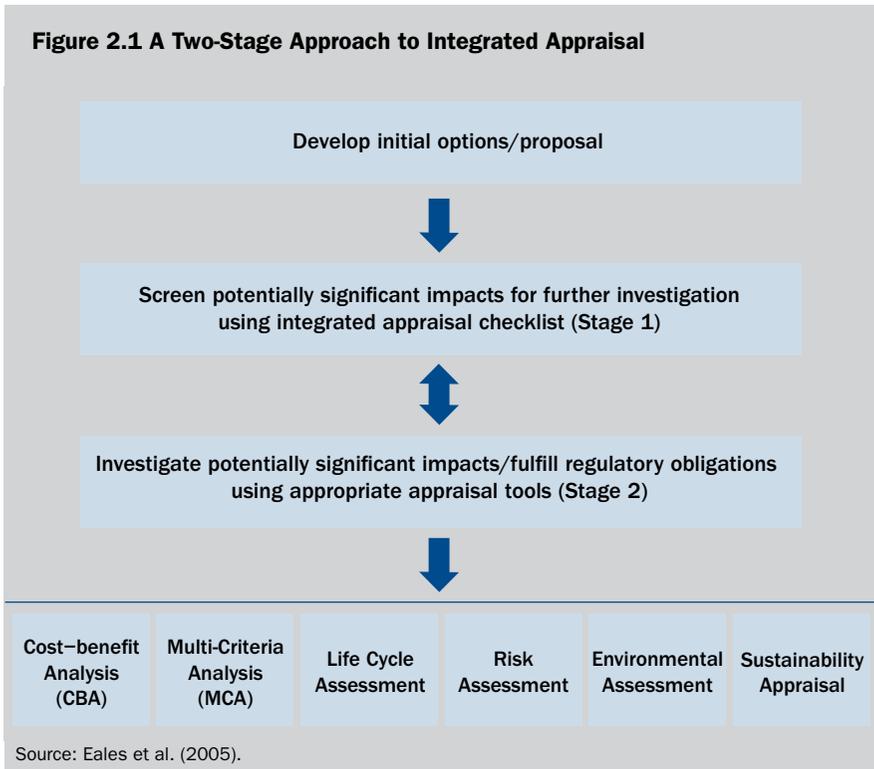
Projects generally have a diverse set of effects and project economic analysis provides a systematic framework to identify, quantify, value, and compare costs and benefits of a project. Thus, economic analysis brings together various diverse impacts in a single comparable measure of project worth. Its great merit is that it converts a variety of disparate effects into a common monetary unit over time and compares these effects systematically. It can be complemented by various forms of checklists of project impacts; for example, including social or environmental effects. However, some have argued that because decision makers need simple and transparent criteria, impact assessments are a viable alternative

²⁷ For example, based on US experience, Shapiro and Schroeder (2008) argue that CBA can be manipulated by analysts to suit their policy preferences

to formal cost–benefit comparisons and that CBA is just one form of assessment that can be carried out.

For example, in the context of the UK, Eales et al. (2005) suggest as a model a two-stage procedure of what they term “integrated appraisal” (Figure 2.1). Initially, a project proposal should be reviewed in terms of its broad economic, social, and environmental implications. This involves collecting data in response to a checklist of questions to allow a qualitative judgment on the potential consequences of a project. At the first detailed stage of “integrated policy appraisal”, these consequences are assessed in more depth. At this point, the less desirable options or aspects of a project can be ruled out. At the second stage of “impact assessment”, more detailed answers are sought on the likely economic, social, and environmental effects. Once this second stage of screening has been completed, a project can be assessed in detail using one or more assessment tools of which CBA will be one of several that might be applied. These tools need not be mutually exclusive and can be used in combination or consecutively.

Figure 2.1 A Two-Stage Approach to Integrated Appraisal



However, while impact assessment in its alternative variants can provide useful data as an input into project analysis, it is conceptually inferior to CBA as long as different types of impacts are considered, since different impacts need to be compared in some way. Clearly there will be some small projects for which a rigorous calculation may be unnecessary given the modest costs involved, but even here short-cut economic calculations with approximate IRR and NPV estimates should be possible as a check on the results of any impact assessment. Table 2.1 contrasts the various impact assessment techniques available for projects from the perspective of the environment. Of these, multi-criteria analysis (MCA) is the one which is closest to CBA in that it aims to incorporate a range of different impacts.

Table 2.1 Merits of Alternative Assessment Techniques for Project/Program Appraisal

Techniques	Description/ Goal	Issues	Similarities/ Differences with Other Techniques (except CBA)	Similarities/ Differences with CBA
Environmental Impact Assessment (EIA)	A systematic procedure for measuring the environmental impacts of a project or policy; looks for ways to minimize environmental impacts without reducing benefits significantly.	Not a comprehensive evaluation procedure. It ignores non-environmental impacts and typically does not include costs.	Similar to SEA but seen as reactive, looking at projects individually. Where weights are attached to impacts, EIA can be similar to MCA.	Has no formal decision rule attached to it.
Strategic Environmental Assessment (SEA)	Instead of single projects or policies, SEA considers programs. Its goal is to look for synergies between individual policies and projects and to evaluate alternatives.	Not a comprehensive decision guide. Issues of time, cost, and non-environmental costs and benefits are rarely addressed.	Seen as more proactive than EIA giving the opportunity for programs to be better designed to minimize harmful impacts.	Considers some of the issues relevant in a CBA, such as with/without principle and consideration of alternatives.

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Table 2.1 continued.

Table 2.1 Merits of Alternative Assessment Techniques for Project/Program Appraisal				
Techniques	Description/ Goal	Issues	Similarities/ Differences with Other Techniques (except CBA)	Similarities/ Differences with CBA
Life Cycle Analysis (LCA)	Identifies environmental impacts as far back and forward in the production/use chain as possible.	Offers no obvious decision rule and does not usually consider non-environmental costs and benefits.	Unlike EIA, looks not just at direct impacts, but aims to capture effects over the whole life cycle of an activity.	Provides detailed physical/quantity data on environmental effects required by CBA.
Risk Assessment (RA)	Involves assessing the health or environmental risks attached to a project. Expressed in various ways (for example, probability of occurrence of health or ecosystem effect, incidence across a defined population, incidence per unit of exposure).	For use as a decision rule, RA requires that estimated risk level be compared with an acceptable level.	Unlike other approaches, acceptable risk level must be identified; for example, by expert judgment or public survey.	Provides similar information to the risk component of CBA, but without the inclusion of monetary values of costs and benefits.
Comparative Risk Assessment (CRA)	Analyzes risks for several alternatives, recommending that with the lowest risk.	Not a comprehensive decision guide since costs are rarely included.	Needs to establish if the least risk level is above what is acceptable.	As with RA, provides similar information to risk analysis in CBA, but without other costs and benefits.
Health–Health Analysis (HHA)	Focuses only on health and compares the estimated effect (for example, lives saved) from a policy with the effect due to the cost of the policy (through higher taxation).	Only addresses health impacts.	Can incorporate health risk of both a policy and its cost. Provides information useful for application of CEA in the health sector.	Provides information useful as an input for CBA in health.

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Table 2.1 continued.

Table 2.1 Merits of Alternative Assessment Techniques for Project/Program Appraisal				
Techniques	Description/ Goal	Issues	Similarities/ Differences with Other Techniques (except CBA)	Similarities/ Differences with CBA
Cost-Effectiveness Analysis (CEA)	Calculates a ratio of cost to a specified measure of impact (cost-effectiveness ratio).	Provides useful information on the ranking of projects, but cannot alone determine whether the least-cost solution should go ahead.	Superior to other measures in that it explicitly introduces cost-efficiency into comparisons.	Useful as an indicator where CBA cannot be used to establish a monetary value for project output.
Multi-Criteria Analysis (MCA)	Links objectives with criteria as a means of achieving objectives and assesses project impact in terms of these criteria.	Generally adopts scores and weights chosen by experts. Unclear how it deals with issues of discounting and changing relative valuations over time.	Useful chiefly as a means of choosing alternatives. If cost is introduced, MCA can be a more complex version of CEA, but involving multiple indicators of cost effectiveness.	MCA differs from CBA in that not all criteria will be given monetary values.

CBA = cost–benefit analysis.
Source: Adapted from Pearce et al. (2006, Chapter 18).

Put simply, for each project, MCA involves identifying a series of project impacts or criteria (for example, employment, travel time, and air quality) and giving these a numerical score in relation to the project's effectiveness (for example, how large is its employment effect, does it save a lot of time, and how far does it improve air quality?). Projects with strong positive effects in relation to a criterion would be given a numerical score at the top end of the range selected (for example, 4 out of 4) and conversely for projects with weak effects (say, 1 out of 4). Each criterion is then assigned a weight and the sum of the weighted scores gives the total project score. Thus, for project j , its score (S) in a multi-criteria analysis is;

$$S_j = \sum m_k * S_k \quad (11)$$

where S_k is the score for criterion k and m_k is the weight placed on k and summation is overall criteria.

A simple numerical example is given in Table 2.2 for two alternative projects, each with three separate impacts by the equity criterion (for example, gender equality), opportunity (through employment creation), and the environment (through improved air quality). The three criteria are given a weight (with gender equality having the highest priority) and project impact in relation to each criterion is given a score. Project B has the higher overall score due to its strong gender impact, while project A has a lower score overall but is a more environment-friendly project.

Table 2.2 Multi-criteria Analysis Example: Two Projects

Criteria	Weights	Project A Score	Project A Impact	Project B Score	Project B Impact
Equity	0.6	2	1.2	4	2.4
Opportunity	0.2	1	0.2	1	0.2
Environment	0.2	4	0.8	2	0.4
Total			2.2		3.0

Note: Score: 1 = weak, 2 = moderate, 3 = significant, 4 = very high.

Source: Adapted from European Commission (2008, Table 2.7).

Similar projects can be compared either by reference to their scores (as above) or in relation to the ratio of scores to capital cost, in a form of cost-effectiveness analysis (CEA). However, it is difficult to use MCA for a basic accept/reject decision on an individual project since an absolute score does not tell a decision maker whether the impacts that have been included are sufficient to accept a project. An accept/reject decision requires a comparison of the with/without scenarios, so that to be meaningful, a project score must be compared with the score derived from the alternative use of the funds that the project uses.²⁸ The key problem with the multi-criteria approach is that scores for individual criterion and their weights are usually based on expert opinion, although in participatory approaches they might reflect the views of the public. Since both scores and weights are judgmental, there are clear risks of inconsistent decisions across a range of projects, where different individuals or groups are consulted. Project economics underlying CBA also has judgmental elements, but since the judgment involved has a

²⁸ Pearce et al. (2006, Annex 18.1) demonstrate the conditions under which MCA and CBA give the same result on the accept/reject decision. It requires equating weights in MCA to economic prices and giving costs a weight of unity and in effect abandoning the basis of MCA.

theoretical foundation it allows a far more systematic and consistent approach to decision taking.

It is for this reason that MCA has not been widely adopted in decision taking within the public sector, either in national governments or international agencies. The standard interpretation now is that impact assessment of various types can produce useful information that can either feed into or complement, but not replace, CBA (Pearce et al. 2006, 276). For example, when discussing multi-criteria and CEA, the European Commission (2008, 66) argues that:

“These approaches cannot be seen as substitutes for CBA but rather as complements for special reasons, or as a rough approximation when actual CBA is impossible. Moreover, they are difficult to standardise and, under the Structural, Cohesion and IPA Funds, should be used with caution in order to avoid inconsistencies across regions and countries that will make assessment of projects by the Commission Services more difficult.”

2.5 Practical Applications

Two of the principal authors of the original methodology reflected on the neglect of this approach in the World Bank, the institution that had been most active in promoting their work initially (see Little and Mirrlees 1994).²⁹ Their position was purist in that while the full procedures of their method were never applied, a simplified form of economic analysis has been used by most donors and even by some developing country governments. The current practice—for example, as recommended for ADB in ADB (1997), and for the World Bank in Jenkins (1997) and Belli et al. (2001)—is to conduct calculations of economic costs and benefits while at the same time examining a project in the context of both sector and macro policy in the economy concerned. Hence, while inevitably, the estimates of benefits and costs at the project level are partial, in the sense that all linkage and iterative effects cannot be quantified, an underlying justification or rationale for a project must be established in

²⁹ World Bank (2010) also finds a declining percentage of World Bank projects that are justified by CBA. The study recommends revisiting World Bank policy for CBA, recognizing the difficulties in quantifying benefits while ensuring analytical rigor. It also calls for reforms in appraisal procedures to ensure the effective use of CBA in decision making.

addition to the standard discounted cash flow indicators of NPV and IRR. However, the latter provides a key check on the reasonableness of the case for a project, since they give the only comprehensive quantitative estimate of acceptability.

Practice in regional development banks follows that of the World Bank in distinguishing between projects with quantifiable benefits and those without. For the former, a cut-off rate of discount (normally 12%) is used as a rationing device so that an acceptable project must have a positive economic NPV at this rate or an economic IRR of above 12%. For the latter category of projects with non-quantifiable benefits in monetary terms, cost-effectiveness comparisons are applied to ensure non-monetary benefits are maximized per unit of cost. There is also evidence from evaluation studies that the initial quality of project economic analysis work prior to implementation is correlated with the likelihood of subsequent project success (at least for the World Bank), since a careful economic analysis helps to identify the key obstacles a project is likely to face (Deverajan et al. 1996, Deininger et al. 1998).

In the period from 1960 to the early 1990s, a number of national governments in developing countries possessed planning agencies which applied national shadow price estimates consistently in the appraisal of public sector projects. The list of such countries is diverse, and includes India, People's Republic of China (from the late 1980s), Chile, Ethiopia, and Jamaica. Many more conducted a simpler form of appraisal that was distinct from financial analysis in omitting transfers and approximating non-marketed or externality effects. As noted above, the appraisal of public sector projects no longer requires major shadow price adjustments in most countries, but developing country governments remain important providers (or partners in public-private initiatives) of physical and social infrastructure whose economic benefits will typically not be captured in market transactions and will therefore not show up in financial appraisals. In addition to its role in the assessment of individual projects, economic analysis is an important aid to the design of sector strategies, for example in relation to the choice of energy sources and technology. The decision whether or not to privatize or to embark on public-private partnerships also requires a systematic comparison of costs and benefits over time and thus also lends itself to this form of analysis.³⁰

³⁰ Jones et al. (1990) provide an example of a cost-benefit approach to privatization in developing countries.

Project economic analysis likewise retains its relevance in the context of higher income economies. It is used routinely when government economists assess the use of public funds in a variety of sectors; for example in road, rail, and air transport, and in the social sectors of health and education. Even where public funds may not be used directly, CBA may nonetheless be used to assess the attractiveness or otherwise of various options, for example in relation to energy strategy (the thermal versus nuclear choice), environmental protection, and the costs of climate change.

A number of Organisation for Economic Co-operation and Development (OECD) governments regularly use CBA to assess their public sector projects. For example, the UK government regularly produces guidance notes on the application of economic analysis in the context of the UK public sector and argues that where there are quantifiable benefits and costs from a project these must be incorporated in a formal cost–benefit comparison (see HM Treasury 2008). This approach is applied as standard practice in the UK road sector where project economic analysis is combined with wider transport modeling (see Chapter 7). The highly influential review on climate change for the UK Treasury (Stern 2007) utilizes the CBA framework to compare the discounted costs of acting now to address climate change with the discounted benefits, defined as long-run avoided costs. Much of the academic debate on the merits of this study focused on the basic question from project economic analysis of whether the correct discount rate was used (Beckerman and Hepburn 2007, Cline 2007, Dasgupta 2008).

Similarly, the European Commission has judged that it is important to use economic analysis in the appraisal of projects financed out of its Structural and Cohesion Funds which are designed to assist the less developed regions of the European Union. During the 1990s, it produced a series of documents to guide the application of project analysis (for example, European Commission 1997). More recently, it has produced a comprehensive guide that incorporates all of the key features of the literature outlined above (European Commission 2008).³¹ This application in a European context highlights the general applicability of the cost–benefit approach. ADB and other regional development banks continue

³¹ The EU Cohesion Policy requires that all major investment projects, normally defined as those costing more than Euro 50 million (but more than Euro 25 million for environmental projects and Euro 10 million for Pre-Accession Assistance projects for new member states) be subject to a formal cost–benefit analysis. Amongst other things the 2008 Guide suggests discount rates of 3.5% or 5.5% varying with country prospects, and the use of economic prices and of risk analysis in project calculations.

to stress that a rigorous application of project economic analysis is a critical component of the planning and approval process. However, as noted above, project economic analysis is defined in broader terms than was once the conventional interpretation of CBA.

A project is viewed in the context of the economy and sector in which it is located, and alternatives are assessed not just technically, but also in terms of ownership and institutional structure. Results are presented not just in terms of single economic NPV and IRR indicators, but also in terms of their probability of occurrence, as well as first-round estimates of gainers and losers. Ex ante economic analysis is followed up at different stages of project life both to monitor progress, anticipate or remove bottlenecks, and to learn lessons for similar future projects. Box 2.1 summarizes the different dimensions of project economic analysis as interpreted by ADB under 10 headings.

Box 2.1 Ten Key Areas of Economic Analysis for ADB Projects

Macroeconomic Assessment: *What macro economic factors affect target sectors and vice versa?*

Assessment of macro and sector policies as they impinge on a project; analysis of economic outlook and key projections; estimation of country-wide national economic parameters like standard conversion or shadow exchange rate factor.

Sector Assessment: *What are the binding constraints to the functioning of markets and efficient and equitable provision of public services?*

Assessment of sector performance, institutional and ownership structure and performance, and policy environment; identification of binding constraints on sector performance, market and non-market failures, and the most appropriate form of development assistance.

Demand Assessment: *How much of the output is wanted? How much are users willing to pay for the output?*

Estimation of demand in a sector; key factors influencing demand; potential willingness to pay for project output; impact of price changes.

Economic Rationale: *What market failures justify the public sector interventions? What non-market or institutional failures justify policy and institutional reforms? Is there a conducive business environment for private sector to participate?*

Description of market or institutional failure to be addressed; rationale for public sector involvement and role of private sector; strategic relevance of proposed project and justification for the form of ADB involvement; relevance of the project to national development plans.

continued on next page.

Box 2.1 continued.

Project Alternatives Analysis: *What is the best way of addressing the market or institutional/policy failure problems?*

Identification of with- and without-project scenarios; assessment of project alternatives in terms of location, scale, technology and timing; least-cost analysis as basis for project selection.

Cost–benefit Analysis: *Will the project benefits exceed the project costs?*

Measurement of main benefits and costs in with- and without-cases; establishing whether some effects cannot be quantified and where necessary using cost-effectiveness analysis; choosing numeraire and price level for shadow pricing; estimating economic NPV and IRR for each independent sub-component and for project as a whole; describing effects that could not be quantified in money terms; conclusions on project acceptability.

Financial and Institutional Sustainability: *Are there enough resources to maintain the flow of project benefits?*

Estimation of financial IRR for revenue generating projects; assessment of whether the financial returns to investors are sufficient to ensure their involvement; indication of expected user charges and any implied subsidies; estimation of fiscal impact of the project and its implications for government involvement; assessment of the institutional capacity of project-related agencies to meet project input and service delivery.

Distribution Analysis: *Who benefits from the project, and by how much?*

Identification of key project stakeholders; assessment of benefit incidence; estimation where possible of allocation of net project income between different groups; where appropriate identification of effects on key target groups, like the poor or ethnic minorities.

Risk and Sensitivity Analysis: *What are the chances that benefits and costs will be realized as anticipated?*

Identification of key project parameters and their likely variability; calculation of the switching value of key parameters and an assessment of the likelihood of its occurrence; quantitative risk analysis based on probability distributions for key variables; assessment of institutional risks; identification of measures to monitor and reduce project risk.

Monitoring & Evaluation: *Do the assumptions maintain their validity throughout the project life?*

Listing key parameters for monitoring; identification of the requirements for future data collection on all key parameters.

Source: Adapted from ADB (2004).

The 10 areas covered in project economic analysis provide a comprehensive framework for analyzing the economic viability of a project in ADB practice. In addition to economic analysis, an environmental impact assessment, a social safeguard assessment, including resettlement and gender issues and poverty, are undertaken. These supplementary assessments provide additional information for economic analysis and generally, the cost of implementing an environmental management plan and resettlement plan, including compensation payments, are included in the project costs. Many aspects of the alternative analysis described in Table 2.1 are covered in this framework, except for explicit use of multi-criteria analysis.

One noteworthy point is the frequently overlooked link between project economic analysis and the design and monitoring framework. The tenth aspect of project economic analysis highlights this link but indicators for monitoring and evaluation are often selected without paying attention to the original project economic analysis. There is a clear synergy that can be harnessed to strengthen the monitoring and evaluation process. For example, many irrigation projects assume a certain level of crop yield and a project's success depends critically on achieving these yields. Similarly, forecast traffic flows and vehicle operating cost reductions determine the economic viability of a road improvement project. Selecting a set of indicators that determine a project's economic viability, in addition to the usual indicators of construction timing and quality would enhance the effectiveness of the monitoring and evaluation process.

2.6 Conclusions

Project economic analysis no longer fuels major academic debate since most theoretical issues have been resolved. The major exception relates to the treatment of risk and in particular, environmental risk and sustainability and how these are best addressed, about which there is still dispute. Environmental externalities have been discussed extensively in the literature over many years, but the recent focus on climate change has heightened awareness that in principle all projects have some environmental consequences, however small. Current thinking emphasizes the need to build into appraisal an awareness of

environmental impacts and where possible, to quantify these as either costs or benefits.

The current policy environment in developing countries differs significantly from that of the 1960–1990 periods after macroeconomic reforms and privatizations in most countries. This has meant that the key issues appraisals need to address, have shifted from macroeconomic distortions to non-market and hard-to-value activities and distributional and poverty concerns. However, the methodology is sufficiently flexible to cope with the demands of the new agenda. There have been major advances in eliciting the stated preferences of individuals and households to approximate WTP for various project outputs. In addition, there has been a revival of interest in tracing through the distributional consequences of projects, without going as far as the controversial step of differentially weighting income flows to different groups.

In practical project applications in sectors such as transport, power, and water, the concepts of demand margin (for incremental consumption of a good) and supply margin (where costs of other producers are saved) are used widely to obtain estimates of tangible economic benefits. Within different sectors, different practical procedures have been developed, although the rigor and accuracy of these approaches vary and a selective application of rigorous contingent valuation studies and other non-market valuation methods offers a promising way forward for valuation of hard-to-value project outputs.

The key point is that for the type of projects supported by governments or donors today, financial appraisal alone, while important as a guide to long-run viability, rarely gives a full picture of a project's economic worth. For these projects, a related but separate economic analysis remains both relevant and important.

3. Theory and Practice in the Choice of Social Discount Rate for Cost-Benefit Analysis: A Survey

3.1 Introduction

A social discount rate (SDR) reflects a society's relative valuation of today's well-being versus future well-being. Choosing an appropriate SDR is crucial for cost-benefit analysis (CBA), and has important implications for resource allocations. Setting the SDR too high could preclude many socially desirable public projects from being undertaken, while setting it too low risks making a lot of economically inefficient investments. Further, a relatively high SDR, by attaching less weight to benefit and cost streams that occur in the distant future, favors projects with benefits occurring at earlier dates; while a relatively low SDR favors projects with benefits occurring at later dates. Choice of the SDR affects not only the ex ante decision of whether a specific public sector project deserves the funding, but also the ex post evaluation of its performance.

Economic efficiency requires that the SDR measure the marginal social opportunity cost of funds allocated to public investment. In a perfectly competitive world without market distortions, the market interest rate is the appropriate SDR. In the real world where markets are distorted, the market interest rate will no longer reflect marginal social opportunity cost of public funds. Economists have proposed several alternative approaches to the choice of the SDR in the presence of market distortions, but there has been no consensus on which is the most appropriate. The differences among these approaches reflect largely differing views on how public investment affects domestic consumption, private investment, and the cost of international borrowing. In cases of very long-term projects with impacts lasting for more than one

generation or even hundreds of years, such as those addressing climate changes and other environment problems, many have argued that the choice of the SDR should not only consider economic efficiency, but also intergenerational equity (Stern 2006).

There are significant variations in public discount rate policies practiced by countries around the world, with developing countries in general applying higher SDRs (8%–15%) than developed countries (3%–7%). These variations reflect the different analytical approaches followed by various countries in choosing the SDR. But more fundamentally, it can be argued that the divergence reflects differences in the perceived social opportunity cost of public funds across countries and in the extent to which the issue of intergenerational equity is taken into consideration in setting the SDR.

The purpose of this chapter is to provide a survey of the vast literature on the SDR that the decades of debate have generated, covering theory, estimation methods, and policy practices.¹ More specifically, the rest of the chapter attempts to ask and answer the following questions:

1. What are the economic arguments for discounting future benefits and costs and analytical approaches to the choice of the SDR?
2. How can an SDR be estimated empirically under each approach?
3. What are the policy practices followed by countries around the world and by multilateral development banks (MDBs) in the choice of the SDR?

The choice of SDR is also an important issue for MDBs, including Asian Development Bank (ADB), and has significant relevance for their operations. In both *ex ante* project economic analysis and *ex post* project performance evaluation, most MDBs estimate and evaluate benefits and costs of development projects using a uniform cut-off discount rate, also called economic internal rate of return (EIRR), of 10%–12%. This chapter is intended not only to provide a reference on project economic analysis for ADB staff, consultants, and concerned government officials of ADB's developing member countries (DMCs), but also to stimulate discussion amongst MDBs on whether the current practice of applying a uniform SDR of 10%–12% to all development projects in all countries is still appropriate in a changing world.

¹ There have been a number of surveys and reviews of this subject in the literature (Stiglitz 1994, Spackman 2004, Evans 2005). Most of these focus either on theory, empirical estimation, or policy practices; not many look at all the three aspects at the same time.

3.2 Theoretical Foundations for the Choice of SDR

3.2.1 Approaches to Discounting Future Benefits and Costs: Unsettled Debate

A public investment project typically incurs costs and generates benefits at different points in time. A common practice in cost-benefit analysis, called discounting, is to express all costs and benefits in terms of their present value by assigning smaller weights to those that occur further away in the future than to those occurring more recently. Discounting, a critical step in determining whether or not a public project is socially desirable, makes costs and benefits with different time paths comparable.²

There are two arguments as to why costs and benefits with different time profiles may not be comparable if not properly discounted. The first is that consumers (or savers) prefer to receive the same amount of goods and services sooner, rather than later. There are two standard textbook explanations for this time preference (Dasgupta and Pearce 1972). The first is that individuals expect their level of consumption to increase in the future, hence marginal utility of consumption will diminish. With this expectation, individuals would have to be paid more than one unit in the future to compensate for sacrificing (saving) one unit of consumption now. The second explanation is that individuals have a positive pure time preference, that is, even if levels of future consumption are not expected to change, they would still discount the future. This explanation however, has been the subject of great controversy (see Box 3.1). Two reasons are often quoted in explaining the pure time preference. One is that consumers are generally “impatient” or “myopic.” The other is the risk of not being alive in the future. According to these lines of reasoning, the rate to discount future benefits and costs should be the marginal social rate of time preference (SRTP), that is, the rate at which society is willing to postpone a marginal unit of current consumption in exchange for more future consumption.³

² Discounting is also required in investment decision making in the private sector where the present value of financial benefits of a project is compared with that of financial costs.

³ Here we disregard the issues involved in aggregating individual preferences into the social preference. See Dasgupta and Pearce (1972) for discussions on these issues.

The second argument for discounting future costs and benefits takes the perspective of a producer (or an investor). According to this, capital is productive and resources acquired for a particular project can be invested elsewhere, generate returns, and so have an opportunity cost. Therefore, to persuade an investor to invest in a project, the expected return from the investment should be at least as high as the opportunity cost of funding, which is the expected return from the next best investment alternative. Following this logic, the rate the investor should use in discounting benefits and costs of a project is the marginal rate of return on investment in the private sector. In the absence of market distortions, this is equivalent to the marginal social rate of return on private investment, also termed marginal social opportunity cost of capital (SOC).

In a perfectly competitive economy without distortions, prices of inputs and outputs would reflect their economic or social values. The supply and demand prices of investible funds are given by SRTP and SOC, respectively. The capital market clears at an interest rate that equates the supply of, and demand for, investible funds. Both SRTP and SOC are equal to the market interest rate. The market interest rate reflects marginal social opportunity cost of investible funds, which is then the appropriate SDR to achieve an efficient allocation of resources in the economy.

In reality, the market is often distorted due to various imperfections. A typical example of imperfection is taxes imposed on corporate incomes and individuals' interest earnings. Other examples are risks, information asymmetry, and externalities. These imperfections create a wedge between SRTP and SOC (with the former generally lower than the latter), and make both deviate from the market interest rate. Under such circumstances, the market interest rate will not reflect the marginal social opportunity cost of public funds, and the latter will vary depending on whether it is measured in terms of SRTP or SOC. What rate then should be used to discount future benefits and costs in cost–benefit analysis? The debate on this has been ongoing for many decades. Four alternative approaches have been put forward: (i) the SRTP, (ii) the SOC, (iii) the weighted average approach, and (iv) the shadow price of capital (SPC) approach. However, there has been no consensus on which is the most appropriate (Boardman et al. 2001). In essence, these different approaches reflect differing views on how public projects affect domestic consumption, private investment, and cost of international borrowing.

Earlier discussions on public sector discounting coincided with the rise of cost–benefit analysis in the 1960s and 1970s. In the 1990s, the choice of the SDR was brought up again in the context of finding a rate to discount the long-term environmental benefits and costs, such as those related to addressing climate change and global warming. Here, the problem of choosing an appropriate discount rate is further complicated by the consideration of intergenerational equity. In the following subsections, we review in some detail how the SDR can be estimated under each of the four approaches, and the latest debate on how to choose a discount rate for very long-lived environmental projects, particularly in the context of calculating the social cost of carbon emissions (Stern 2006, Nordhaus 2006, and Dasgupta 2006).

3.2.2 Social Rate of Time Preference

The SRTP is the rate at which a society is willing to postpone a unit of current consumption in exchange for more future consumption. The use of SRTP as the SDR, supported by Sen (1961), Marglin (1963a and 1963b), Diamond (1968), and Kay (1972), is based on the argument that public projects displace current consumption, and streams of costs and benefits to be discounted are essentially streams of consumption goods either postponed or gained. Two alternative methods have been suggested for empirical estimation of SRTP. One is to approximate it by the after-tax rate of return on government bonds or other low-risk marketable securities. Although this is straightforward, a major concern is that individuals may not express all their preferences concerning the future in the marketplace and, even if they do, their preferences expressed as individuals may not be the same as their preferences expressed when they see themselves as part of a society. Society as a whole would have a lower rate of discount in its collective attitude than the observed market rates, which could reflect individuals' myopia (Dasgupta and Pearce 1972).

The other method is to use a formula named after the renowned British economist Frank P. Ramsey. According to Ramsey's formula, derived from a growth model, SRTP is the sum of two terms: the first is a utility discount rate reflecting the pure time preference and the second is the product of two parameters—the elasticity of the marginal

utility of consumption⁴ and the annual rate of growth of per capita real consumption (Ramsey 1928). The second term of the formula reflects the fact that, when consumption is expected to grow in the future, people will be less willing to save in the current period to obtain more in the future, because of diminishing marginal utility of consumption. Using the Ramsey formula to empirically estimate SRTP requires information on the utility discount rate (ρ), elasticity of marginal utility of consumption (θ), and annual rate of per capita real consumption growth (g). The choice of g is relatively straightforward while the choice of ρ and θ is more difficult, as it involves normative value judgments, and has been a subject of intense debate, as discussed in Box 3.1.

The utility discount rate, ρ , is conceptually considered as consisting of two components, one related to individuals' impatience or myopia and the other related to the risk of death or human race extinction.⁵ Many empirical studies set the first component to zero often on ethical grounds (see, for example, Kula 1984, 1987, and 2004; Cline 1992; Stern 2006). It has also been argued that considering myopia in estimating SRTP implies introducing irrationality into the decision-making process, which is inconsistent with the principle of cost–benefit analysis, i.e., to bring rationality into investment decisions (Kula 1984). The difficulty in empirically estimating this first component of pure time preference could also be a reason why many studies have ignored it. On the other hand, setting this to zero does lead to some paradoxical results (see Box 3.1). Among empirical studies that consider this to be positive, the suggested range is 0%–0.5% (OXERA 2002). Scott (1977 and 1989) argues that the long-run savings behavior in the United Kingdom (UK) is consistent with a value of 0.3%–0.5% for this component of ρ . Table 3.1 provides a survey of some of the empirical studies on the utility discount rate including both of its two components. The suggested range is 1%–3%.

For the component of the utility discount rate related to the risk of not being alive in the future, the controversy is not on whether it should be considered; rather, it is on how to measure this risk. Some attempt to estimate individuals' survival probability and risk of death using death

⁴ The elasticity of marginal utility of consumption is the percentage change in individuals' marginal utility corresponding to each percentage change in consumption.

⁵ In the literature, some authors relate the pure time preference only to the first component while most relate it to both. In this paper, we follow the convention used by most authors: pure time preference reflects both individuals' impatience and risk of not being alive in the future.

rate statistics (Kula 1984, 1987, 2004). Others argue that individuals' risk of death is not relevant to the derivation of the social time preference; what is relevant is the changing life chance for whole generations (Pearce and Ulph 1999).

Box 3.1 The Debate on Pure Time Preference

Many argue that the positive pure time preference, which implies valuing utility of future generations less than the present generation, is ethically indefensible (Ramsey 1928, Pigou 1932, Harrod 1948, Solow 1974). Others, while admitting that ethically all generations should be treated alike, point out that a zero rate of pure time preference implies a savings rate excessively higher than what we normally observe and contradicts real world savings behavior, leading also to other paradoxical results (Arrow 1995). There are also those who argue that the risk of death, or mortality, is a rational enough reason for positive pure time preference (Eckstein 1961). This argument, although more amenable to empirical investigation and less prone to fundamental disputes about value judgments, is also subject to disagreement about what precise risks are being discussed (Pearce and Ulph 1999). Dasgupta and Pearce (1972) highlight the problem of considering risk-of-death time preference in calculating the SDR, because the social time preference relates to society, and not to an aggregate of individuals; although individuals are mortal and society is not. Among more recent empirical studies, some authors look at the increasing risk of death, or changing survival probability, for an individual as one gets older (Kula 1985, 1987, 2004; Evans and Sezer 2004). Pearce and Ulph (1999) highlight problems of this approach, and argue that when dealing with very long-lived projects, the appropriate risks are not so much the increasing probability of death of a single individual, but what is happening to the life chances of whole generations. Newbery (1992) attempts to measure this risk by estimating the perceived risk of the end of mankind in 100 years. The *Green Book* of the UK HM Treasury refers to this as a catastrophe risk, that is, the likelihood that there will be some events so devastating that all returns from policies, programs, or projects are eliminated, or at least radically and unpredictably altered (HM Treasury 2003). The Stern Review defines this as the risk of extinction of the human race and argues that such risks could arise from possible shocks such as a meteorite, a nuclear war, or a devastating outbreak of some diseases.

Source: Zhuang, et al. (2007).

Table 3.1 Empirical Estimates of the Utility Discount Rate

Source	Empirical estimates	Theoretical basis
Scott (1977)	1.5%	Component reflecting myopia is 0.5%, and that reflecting the changing life chance due to the risk of total destruction of a society is 1.0%
Kula (1985)	2.2%	Reflecting average annual survival probability in the UK during 1900–1975
Kula (1987)	1.2%	Reflecting average annual probability of death in the UK in 1975
Scott (1989)	1.3%	Component reflecting myopia is 0.3%, and that reflecting the changing life chance due to the risk of total destruction of a society is 1.0%
Newbery (1992)	1.0%	Perceived risk of the end of mankind in 100 years
Dynamic Integrated Model of Climate and the Economy (DICE) model (Nordhaus 1993)	3% per year	Utility discount rate reflecting pure social time preference, determined by calibrating the DICE model to match actual data
Pearce and Ulph (1995)	1.1%	Reflecting the average annual probability of death in the UK in 1991
Arrow (1995)	1%	Utility discount rate reflecting pure social time preference, and matching the observed savings behavior
OXERA (2002)	Myopia = 0–0.5% Risk of death = 1.1% with a projected change in the near future to 1.0%	Based on previous studies and projected and recent average annual death rates in the UK
Evans and Sezer (2004)	1.0–1.5%	1% for EU countries and 1.5% for non-EU countries, reflecting catastrophe risks
Kula (2004)	1.3%	Reflecting the average annual death rate in India during 1965–1995
Evans (2006)	1%	Based on the approximate average annual death rate in 2002–2004 in 15 countries of the European Union
Stern (2006)	0.1%	Probability of human race extinction per year

EU = European Union, UK = United Kingdom.
Source: Zhuang, et al. (2007).

Empirical estimates of the elasticity of marginal utility of consumption (θ) also vary from one study to another. Three different approaches have been used: direct survey methods; indirect behavioral evidence; and revealed social values (see a recent review by Evans 2005). The survey methods focus on measuring risk and inequality aversion⁶ from responses to specially designed survey questions. The indirect behavioral evidence is based on observed consumption behavior from empirically estimated consumer demand models. The third approach in estimating θ involves inference from government behavior revealed through spending and tax policies. A survey of empirical estimates of θ based on the three approaches indicates that its values mostly fall within the range from 1% to 2%, except for a few outliers (Table 3.2). The differences suggest that the results are sensitive to model specification, level of aggregation in the data, choice of estimators, sample size, and the length of sample periods.

Table 3.2 Empirical Estimates of the Elasticity of Marginal Utility of Consumption

Source	Empirical Estimates	Dates
A. Survey Method		
Barsky et al. (1995)	Approximately 4.0	Reflecting risk aversion of the US middle-aged who were surveyed
Amiel et al. (1999)	0.2–0.8	Reflecting inequality aversion of US students who were surveyed
B. Indirect Behavioral Evidence		
<i>Constant elasticity demand models</i>		
Kula (1984)	1.56	Canada: 1954–1976 data
Kula (1984)	1.89	US: 1954–1976 data
Evans and Sezer (2002)	1.64	UK: 1967–1997 data
Evans (2004a)	1.6	UK: 1965–2001 data

continued on next page.

⁶ Risk aversion measures the reluctance of an individual to accept a bargain with an uncertain payoff rather than another bargain with a more certain but possibly lower expected payoff. Inequality aversion measures an individual’s tolerance to income inequality. Risk aversion is closely related to inequality aversion, and both are closely related to the elasticity of marginal utility of consumption.

Table 3.2 continued.

Table 3.2 Empirical Estimates of the Elasticity of Marginal Utility of Consumption		
Source	Empirical Estimates	Dates
Kula (2004)	1.64	India: 1965–1995 data
Evans et al. (2005)	1.6	UK: 1963–2002 data
Percoco (2008)	1.28	Italy: 1980–2004 data
<i>Almost ideal demand system</i>		
Blundell (1988)	1.97	UK: 1970–1984 data
Evans (2004b)	1.33	France: 1970–2001 data
<i>Lifetime consumption model</i>		
Blundell et al. (1994)	1.2–1.4	UK: 1970–1986 data
<i>Quadratic almost ideal demand system</i>		
Blundell et al. (1993)	1.06 1.06–1.37	Aggregate model Micro models UK: 1970–1984 data
Banks et al. (1997)	1.07	UK: 1970–1986 data
C. Revealed Social Values		
Cowell and Gardiner (1999)	1.28–1.41	UK: 1999–2000 data
Evans and Sezer (2004)	1.5	UK: 2001–2002 data
Evans (2005)	1.25–1.45	Five major OECD countries (France, Germany, Japan, UK, US): 2002–2003 data
EU = European Union, OECD = Organisation for Economic Co-operation and Development, UK = United Kingdom, US = United States. Source: Zhuang, et al. (2007).		

With estimates of ρ , θ , and g , SRTP can be calculated using the Ramsey formula. Box 3.2 provides an illustration.

A major criticism on using SRTP as the SDR is that it is purely a measure of the social opportunity cost in terms of foregone consumption and ignores the fact that public projects could displace or crowd out private sector investment if they cause the market interest rate to rise

Box 3.2 The Ramsey Formula

Consider the following Ramsey growth model where the representative agent maximizes its life-time welfare subject to intertemporal constraint (Ramsey 1928):

$$\text{Maximize } \int_0^{\infty} U(c_t) e^{-\rho t} dt \quad (1)$$

$$\text{subject to } \dot{k}_t = f(k_t) - c_t \quad (2)$$

where $U(\cdot)$ represents a time-variant utility function with properties of $U'(\cdot) > 0$ (the marginal utility of consumption is positive) and $U''(\cdot) < 0$ (the marginal utility of consumption diminishes); ρ is a utility discount rate reflecting pure time preference; c_t is consumption at time t ; $f(\cdot)$ represents a production function; and \dot{k}_t is net investment at time t .

Maximization requires

$$U'(c_t) f'(k_t) + U''(c_t) \dot{c}_t - \rho U'(c_t) = 0 \quad (3)$$

where \dot{c}_t is change in consumption at time t . Equation (3) can be simplified to

$$r = f'(k_t) = \rho + \Theta g \quad (4)$$

where r is the rate of return to savings; $\Theta = -\frac{U''}{U'} c$ is the elasticity of marginal utility of consumption representing preference and is also known as the coefficient of relative risk aversion; and $g = \dot{c}_t/c_t$ is the growth rate per capita consumption. Equation (4) is the familiar Ramsey formula, which states that households choose consumption so as to equate the rate of return to savings to the rate of pure time preference plus the rate of decrease of the marginal utility of consumption due to growing per capita consumption.

Following Evans and Sezer (2004), the rate of pure time preference ρ is assumed to be 1.5%, elasticity of marginal utility of consumption Θ is assumed to be 1.3, and the average growth rate of per capita real consumption g is the average annual growth rate of per capita real GDP from 1970 to 2004 (Penn World Tables 6.1). The Ramsey formula yields the following estimates of SRTP for four selected Asian countries (see box table).

Box Table. Empirical Estimates of SRTP for Selected Asian Countries

	ρ (%)	g (%)	Θ	SRTP (%)
Indonesia	1.5	3.55	1.3	6.1
Malaysia	1.5	4.88	1.3	7.8
Singapore	1.5	4.48	1.3	7.3
Japan	1.5	2.34	1.3	4.5

Source: Zhuang, et al. (2007).

(Baumol 1968, and Harberger 1972). If additional public investment is made at the cost of displacing private investment, its marginal social opportunity cost should also reflect what the displaced private investment would otherwise bring to the society, which can be measured by the marginal social rate of return on private sector investment—SOC.⁷ Since SRTP is generally lower than SOC because of the wedge created by market distortions such as taxes, this raises the possibility that too many low-return investments in the public sector would be undertaken when SRTP is used as the SDR.

3.2.3 Marginal Social Opportunity Cost of Capital

The proposal for using the marginal social opportunity cost of capital (SOC) as the SDR, advocated by Mishan (1967), Baumol (1968), and Diamond and Mirrlees (1971a and 1971b), among others, is based on the argument that resources in any economy are scarce; that the government and the private sector compete for the same pool of funds; that public investment displaces private investment dollar by dollar; and those devoted to public sector projects could be invested in the private sector. Therefore, public investment should yield at least the same return as private investment. If not, total social welfare can be increased by reallocating resources to the private sector, which yields higher returns.

It has been suggested that SOC could be approximated by the marginal pre-tax rate of return on risk-less private investments. A good proxy for this is the real pre-tax rate on top-rated corporate bonds (Moore et al. 2004). Box 3.3 provides an illustration of estimating the marginal rate of return based on Moody's AAA bonds. Some have argued that SOC, as estimated in Box 3.3 should be adjusted downward for a number of reasons (Lind 1982, Boardman et al. 2001). Firstly, in theory, the marginal pre-tax rate of return, rather than the average rate, should be used in estimating SOC. The marginal rate of return will be lower than the average rate as rational businessmen will make their best deal first. Second, the rate of return on private investment includes premiums to compensate investors for risks that are generally higher than those for

⁷ This can be approximated by the pre-tax rate of return on private investment. See discussions in the next subsection.

Box 3.3 Estimating Social Opportunity Cost from Yields on Corporate Bonds

Based on the method used by Boardman et al. (2001), the average annual yield on Moody's AAA long-term corporate bonds was estimated at 6.81% from January 1947 to December 2005 in the United States. Applying the 2004 corporate tax rate of 40% (KPMG 2004), the nominal pre-tax return on bonds was calculated at $[0.0681 / (1-0.38)] = 11.35\%$. A proxy for the expected rate of inflation is the average annual inflation rate, which was 3.78% between 1947 and 2005 in the United States. Therefore, the real pre-tax rate of return on top-rated corporate bonds in the US is $[(0.1135 - 0.0378) / (1+0.0378)] = 7.29\%$, which approximates the marginal social opportunity cost of capital.

Source: Zhuang, et al. (2007).

public sector investment. Third, returns on private investment as SOC may also be contaminated by market distortions such as externalities and monopolistic pricing.

Dasgupta, Marglin, and Sen (1972), on the other hand, note that the argument for using SOC as the SDR is only justified in the context of a two-period model where the total amount of capital available for investment is fixed independently of project choice in the public sector. In this case, the public investment displaces (or crowds out) private investment dollar for dollar, and the marginal rate of return on private investment (inclusive of taxes) provides an adequate measure of SOC. But when either assumption (two-period model or fixed amount of capital) is dropped, the argument would not hold anymore. If capital needed for financing public projects is partially satisfied by consumers postponing their current consumption, the return required by consumers usually is less than the marginal rate of return on private investment; hence, the SDR should be lower than SOC.

3.2.4 The Weighted Average Approach

Previous discussions suggest that using SRTP to discount future costs and benefits is problematic since it does not take into account impacts of public projects on funds available for private investment. Using SOC as the SDR, on the other hand, assumes that public investment only displaces private investment and not private consumption, which is also

not always true in reality. The weighted average approach, associated with contributions by, among others, Harberger (1972), Sandmo and Drèze (1971), and Burgess (1988), attempts to reconcile the SRTP approach with that of SOC.

Proponents of the weighted average approach recognize that sources of funds available to public projects may come from displacing private investment, inducing consumers to postpone current consumption, and, in the case of an open economy, borrowing from international capital markets. The social opportunity costs of funds from these various sources are different because of market distortions such as taxes. Thus, the SDR should be the weighted average of SOC, SRTP, and the cost of foreign borrowing, with weights reflecting proportions of funds obtained from their respective sources. Harberger (1972) argues that SOC may differ from one productive sector to another and SRTP could also vary among different groups of savers (reflecting, for instance, different tax brackets); therefore, SOC and SRTP themselves should be the weighted average of those of various productive sectors or saver groups. Burgess (1988) suggests that the weights depend also on the degree of complementarity or substitutability between public and private investment, but points out that the positive externalities of public investment due to its complementarity can be considered as part of benefit streams and, in that case, no adjustments to the weights are necessary.

For a closed economy, if the supply of funds is perfectly inelastic, a public sector project will displace only private investment, so the weight for SRTP will be zero and the SDR will be equal to SOC. If, on the other hand, the demand for funds is perfectly inelastic—a public project will only displace current consumption—the weight for SOC will be zero, and the SDR will be equal to SRTP. In general, it is believed that both the supply and demand of investible funds respond to changes in the market interest rate, so the SDR will lie somewhere between the two extremes. Harberger (1972), however, argues that the accumulated econometric evidence on investment functions clearly shows that many categories of investment are quite sensitive to changes in the interest rate, while evidence that savings are responsive to interest rate changes is only scanty. Hence, there is a reasonable presumption that the relevant weighted average will be reasonably close, if not precisely equal, to SOC.

For an open economy where capital is mobile across countries, it is expected that the domestic interest rate will be related in some way to the interest rate at which the country can borrow in the world capital market

(Sandmo and Drèze 1971, Edwards 1986, Lind 1990). In the extreme case of a small open economy with perfect capital mobility, risk neutrality, pegged exchange rate (with zero expected devaluation), and an infinitely elastic supply of foreign capital, public projects will displace neither domestic consumption nor private investment. The weights for SOC and SRTP will, therefore, both be zero and the SDR will be equal to the international borrowing rate. However, Edwards (1986) argues that even a small economy with perfect capital mobility will face an upward-sloping supply curve of foreign capital. One justification is that a higher level of foreign indebtedness could be related to a higher probability of default as perceived by lenders, and to a higher cost at which this particular country can borrow from the international capital market. In this case, a public project that is (partially) financed with additional foreign debt will result in a higher rate charged on foreign loans, and perhaps, higher domestic interest rates as well since the two are linked. Therefore, a public project will be financed partially by an increase in foreign debt, and partially by an increase in private savings and a reduction in private investment. Then, in the presence of country risk premiums, the SDR will be a weighted average of SOC, SRTP, and the international borrowing rate inclusive of risk premiums.⁸ In another extreme, if a country faces credit rationing from abroad, the new demand for public funds will be met fully by additional domestic private savings and displaced private investment. Then, the SDR will be a weighted average of only SOC and SRTP.

A key challenge in the empirical estimation of the SDR using the weighted average approach is to determine the weights attached to SRTP, SOC, and the international borrowing rate, as well as weights for SRTPs of various saver groups and for SOCs of various productive sectors. Harberger (1972) provides a formula for calculating the SDR using the weighted average approach in the case of a closed economy, where the weights are estimated from interest derivatives (the responses of private investment and savings to changes in market interest rates), which can also be expressed in terms of elasticities. Sandmo and Drèze (1971) expand the formula to an open economy context by incorporating

⁸ Edwards (1986) argued that whether this higher interest rate should be considered as a higher cost of borrowing will depend on the relationship between the probability of default as perceived by the lenders and by borrowers. If the perceived probability of default is the same for lenders and borrowers, the higher interest rate charged to the developing country will not represent a higher economic cost of foreign funds. But in general, the perceived probability of default is different between lenders and borrowers (the former is mostly greater than the latter); thus the risk premium does constitute an economic cost for a borrowing country.

the international borrowing rate, with weights being estimated from the interest derivatives of the domestic and foreign supplies of funds. Based on Harberger and Jenkins (2002), Box 3.4 provides an example using the weighted average approach to estimate the SDR, assuming varying SRTP among saver groups, varying SOC among productive sectors, taxation on interest earnings (including withholding tax for foreign savers) and on investment returns, and an upward-sloping supply curve of foreign capital.

A major criticism on the weighted average approach is that, while it recognizes that costs of public investment can displace private investment, it assumes that benefits will be consumed immediately and ignores the fact that they could also be reinvested in the private sector, generate future consumption, and bring more social value than if they were consumed immediately. Recognizing a higher social cost of displaced private investment than displaced consumption, while ignoring the higher social value of project benefits that are reinvested, rather than immediately consumed, leads to over-discounting of project benefits. This over-discounting will be higher the farther in the future the benefits occur. Therefore, compared to SRTP, the weighted average approach could be biased against long-term projects (Zerbe and Dively 1994).

3.2.5 Shadow Price of Capital Approach

The SPC approach, associated with contributions by Feldstein (1972), Bradford (1975), and Lind (1982) among others, also attempts to reconcile the SRTP approach with that of SOC and, at the same time, addresses the limitation of the weighted average approach. The SPC approach recognizes that while costs of a public project can displace private investment, its benefits can also be reinvested in the private sector. In terms of generated future consumption streams, these benefits are worth more to society than if they are consumed immediately. Thus, the total cost of a public project is the sum of the current consumption that is directly displaced and those future consumption streams that are foregone due to the displacement of private investment. Similarly, the total benefit of a public project is the sum of those immediately consumed and those future consumption streams generated from reinvestment.

Box 3.4 Estimating the SDR Using the Weighted Average Approach

According to the weighted average approach, also known as Harberger approach, the social discount rate can be expressed as

$$\bar{\delta} = \alpha SOC + (1 - \alpha - \beta) i_f + \beta SRTP \quad (1)$$

where $\bar{\delta}$ denotes the social discount rate, i_f is the government's real long-term foreign borrowing rate, α is the proportion of funds for public investment obtained at the expense of private investment, β is the proportion of funds obtained at the expense of current consumption, and $(1-\alpha-\beta)$ is the proportion of funds from foreign borrowing. SRTP and SOC are measured, respectively, by the rate of real return on savings exclusive of (i_f) and investments inclusive of (r_j). Expressing the weights attached to different funding sources in terms of elasticities of demand and supply of funds with respect to changes in interest rates, equation (1) becomes:

$$\bar{\delta} = \frac{\sum_i \varepsilon_i (S_i/S_t) i_f + \varepsilon_f (S_f/S_t) i_f - \sum_j \varepsilon_j (I_j/I_t) r_j}{\sum_i \varepsilon_i (S_i/S_t) + \varepsilon_f (S_f/S_t) - \sum_j \varepsilon_j (I_j/I_t)} \quad (2)$$

where ε_i , ε_f , ε_j are respective elasticities of savings, supply of foreign capital, and private investment with respect to the interest rate. S_i/S_t and S_f/S_t are the shares to the total savings by various groups of domestic savers and foreign savers. I_j/I_t is the investment share of various business sectors.

Using Equation (2) and 1988 – 1989 data for Papua New Guinea, Harberger and Jenkins (2002) present an example of calculating the social discount rate, which they call economic opportunity cost of capital. The example assumes that there are four saver groups: households, business, government, and foreign. For each saver group, the real rate of return on savings was calculated from the nominal market interest rate by taking out the respective taxes and inflation. In estimating the real marginal cost of foreign borrowing, further adjustment was made by taking into consideration the effects of new borrowing on the country's foreign borrowing rate. In the case of investors or demanders of funds, they were classified into the following sectors: housing, agriculture, manufacturing, government, and mining. The nominal pre-tax rate of return on investment for each sector was again calculated from the normal market interest rate by adding respective tax rates.

These rates, together with the estimated saving shares and elasticities of various saver and investor groups, yield an estimated economic cost of capital, or the social discount rate, of 11.76%. Detailed calculations are in the Appendix.

Source: Harberger and Jenkins (2002).

The SPC approach involves four steps. The first is estimating SPC, which is the present value of streams of future consumption foregone arising from displacing one unit of private investment or the present value of future consumption streams generated from reinvesting one unit of project benefits in the private sector. The second step involves, for each time period, converting all the costs and benefits that either displace or generate private investment into consumption equivalents by multiplying them by SPC. The third step is adding these costs and benefits to the other portions of costs (in the form of directly displaced consumption) and of benefits (in the form of immediate consumption), respectively. Finally, the fourth step discounts the total cost and benefit streams at SRTP to calculate the net present value (NPV) (see Box 3.5).

Zerbe and Dively (1994) discussed a number of situations where costs and benefits need not be adjusted by SPC:

- (i) For a closed economy, if the fraction of benefits that accrue to private capital is equal to the fraction of costs that displace private investment, adjusting the costs and benefits by SPC does not change the sign of the NPV of a project. In this case, a project is socially desirable if the NPV is positive when applying SRTP as a discount rate to the ordinary costs and benefits. This is likely the case for many environmental projects where benefits are costs avoided whose financing is similar to initial costs.
- (ii) For an open economy, if the supply of capital is highly or perfectly elastic, the displaced and generated private investment will be small and similar in size, or both will be zero, and it is then sufficient to discount benefits and costs by the international borrowing rate without adjusting them by SPC.
- (iii) For least-cost analysis (also referred to as cost-effectiveness analysis [CEA]), the goal is to compare the costs of alternative methods of producing the same output. As long as the financing of the various alternatives is similar, adjustment by SPC is not warranted.

When project costs and benefits need to be adjusted by SPC, empirical estimation of SPC is warranted, which requires information on the following parameters: SOC, SRTP, depreciation rate, and marginal propensity to save. Lyon (1990) provides two alternative formulas

to calculate SPC. One applies when the savings rate is expressed in terms of the gross return, and the other applies when the savings rate is expressed in terms of the return net of depreciation. Box 3.5 provides these formulas. The application of the SPC approach requires further information on proportions of displaced consumption and private investment due to project costs, and proportions of generated consumption and reinvestment due to project benefits.

The SPC approach, although theoretically attractive (see Feldstein 1972, Bradford 1975, Lind 1982), is difficult to implement. The value of SPC is very sensitive to the values of SRTP and SOC, to how depreciation and reinvestment are assumed, and to the length of life of a project. Lyon (1990) shows that the value of SPC could vary from about one to infinity, depending on different assumptions on the values of the various parameters. Harberger and Jenkins (2002) argue that if the SPC approach is employed, a different SPC has to be estimated for every project according to the length of life of the project. This could be very confusing

Box 3.5 The Shadow Price of Capital Approach

Consider a project with a lifespan of n years, benefit streams, B_t , and cost streams, C_t . The net present value of the project will be

$$NPV = \sum_{t=0}^n \frac{B_t^* - C_t^*}{(1+i)^t} = \sum_{t=0}^n \frac{B_t[\phi_b V + (1 - \phi_b)] - C_t[\phi_c V + (1 - \phi_c)]}{(1+i)^t} \quad (1)$$

where B_t^* is the consumption equivalents of benefits at time t ; C_t^* is the consumption equivalents of cost at time t ; ϕ_b is the fraction of benefits that return to the private sector for investment; ϕ_c is the fraction of costs that displace private investment; i is SRTP; and V is SPC. Lyon (1990) provides two alternative formulas to calculate V :

$$V = \frac{r - sr}{i + d - sr} \quad (2)$$

where r is the gross rate of return on private investment prior to depreciation, d is the depreciation rate, and s is the rate of savings from the gross return; and

$$V = \frac{\lambda - \sigma\lambda}{i - \sigma\lambda} \quad (3)$$

where λ is the rate of return from private investment net of depreciation, and σ is the rate of saving from the net return.

Source: Zerbe and Dively (1994).

for policy makers in the government decision-making process, many of whom are non-economists.

3.2.6 Discounting Intergenerational Projects

From the mid-1990s, with the growing concerns over climate change, global warming and other environmental problems, there has been renewed interest on whether and how discounting should be applied to long-term projects, the effects of which spread over more than one generation (more than 30–40 years) or even hundreds of years, and whose present values are extremely sensitive to the choice of the discount rate. In evaluating intragenerational projects, it could be argued that the main issue is to achieve efficient allocation of scarce resources, thus the discount rate should reflect the economic opportunity cost of capital. When evaluating intergenerational projects, identifying an appropriate discount rate involves an additional challenge of considering intergenerational equity.

What is common to the four approaches described above is that the discount rate, whatever it is, is time-invariant, implying that discounting would be exponential. With a constant discount rate, benefits and costs that occur in the distant future will become very small in terms of their present value. Thus, it seems not worth investing even a little to avoid potential catastrophic consequences of some environment problems if they will occur only far into the future. Since beneficiaries of projects dealing with such types of problems will be future generations, attaching very small weights to future benefits implied by exponential discounting does pose a question of whether it is “ethically indefensible.” Put simply: why should the well-being derived from the same level of consumption of any future generation be given less weight than for the current generation on the grounds of individuals being impatient? Many believe that this is not ethical, and the pure rate of time preference should be zero. Others argue that weighting generations equally leads to paradoxical and even nonsensical results (see Box 3.1). Apart from the ethical issue, exponential discounting implies that the importance of a cataclysmic event happening 4 centuries from now is much less significant relative to that of a cataclysmic event occurring, say, 3 centuries from now. Weitzman (1998) argues that “almost no one really feels this way about the distant future.”

Some have proposed a solution to the problem, which involves using a declining discount rate, namely, “hyperbolic discounting” (Weitzman 1994, 1998, 2001; Henderson and Langford 1998; Cropper and Laibson 1998). Hyperbolic discounting hypothesizes that the discount function with regard to time is shaped like a hyperbola, thus allowing the discount rate to decline with time according to some predetermined trajectory and raising the weight attached to the welfare of future generations. According to Weitzman (1998), “near future” and “far future” should be viewed differently because of different levels of uncertainties involved. Compared to the near future, the far distant future has much greater uncertainties about economic growth, rate of capital accumulation, state of the environment, pace of technological progress, rate of pure time preference, etc. As a result, there is a wide range of possible discount rates for the far future, and a “certainty equivalent discount rate” should be calculated as a weighted average of these possible discount rates. He shows that the “certainty equivalent discount rate” equals the lowest possible discount rate.⁹ This way he explains why different discount rates should be used for near future projects and far distant future ones. Over the past decades, there has also been increasing evidence from experiments conducted by economists and psychologists, which suggests that people do use a declining discount rate in making inter-temporal choices (Weitzman 2001).

A conceptual problem with time-declining discounting is that it leads to time-inconsistent planning: a person who applies a hyperbolic discount rate may not carry out the consumption plans made today and may reverse the decisions in the future even though no new information emerges (Cropper and Laibson 1998). Due to this type of problem, some have suggested that intergenerational equity should be treated directly rather than through adjusting the discount rate (Lesser and Zerbe 1995, Schelling 1995). More specifically, some argue that in the context of global warming mitigation, one should not simply lower the discount rate used to evaluate costs and benefits of projects; in cases where there may be significant irreversibility and potential questions of intergenerational equity, one should not rely on the project discount rate alone. Instead,

⁹ This is best illustrated through an example (Spackman 2004). Suppose in the long term that the discount rate is believed to be either 2% or 4%, with equal likelihood. The project benefits are worth \$1 million in 500 years. The present value of the \$1 million in 500 years would be \$50 using 2% discount rate, and almost \$0 using 4% discount rate. Since two discount rates have an equal likelihood to occur, the expected present value of the project is about \$25, the average of \$50 and \$0. This gives an “effective discount rate” of 2.1%, close to the lower end of two possibilities.

a full analysis of all these concerns and options should be carried out separately and explicitly for informed choice and decision-making (Lind 1997, Nordhaus 1999, Kopp and Portney 1999, and Toman 1999). Henderson and Bateman (1995) suggest that discount rate sensitivity analysis may include hyperbolic discount rate results along with classical constant discount rate results for intergenerational projects.

Despite the debates, there appears a general agreement that the SRTP should be used in discounting intergenerational projects. The Stern Review (2006) applies an SRTP of 1.4% to discount damages of global warming, estimated using the Ramsey formula. It is the sum of two numbers: 0.1%, which is the rate of pure time preference reflecting solely the assumed risk of human race extinction,¹⁰ and 1.3%, which is the product of a unity elasticity of marginal utility of consumption and an expected annual growth rate of per capita real consumption reflecting the diminishing marginal utility of consumption. Nordhaus (2006), in his critique of the Stern Review, argues that the near-zero rate of pure time preference combined with the unity elasticity of the marginal utility of consumption is inconsistent with key economic variables observable in the real world such as real interest rates and savings rates. To match the observed values of these variables, either a higher rate of pure time preference or higher elasticity of marginal utility of consumption has to be assumed, implying a much higher social discount.

Using the Dynamic Integrated Model of Climate and the Economy (DICE), he shows that if the rate of pure time preference is raised from 0.1% (as assumed by the Stern Review) to 3% at the beginning, then declining slowly to about 1% in 300 years (matching key economic variables observable in the real world), the optimal base year (2005) carbon price would decrease from \$159 to \$17–20 per ton.¹¹ He concluded that the radical revision of the economics of climate change proposed by the Stern Review depends decisively on the assumption of a near-zero rate of social time preference.

¹⁰ The Stern Review therefore disregards the “impatience” related argument for discounting.

¹¹ Developed by William D. Nordhaus, the DICE model is one of the economic models widely used to estimate costs and benefits of different paths for slowing climate change and for analyzing the impact of control strategies over time (Nordhaus 1994). The optimal carbon price, or carbon tax, sometimes also called the “social cost of carbon”, is the calculated price of carbon emissions that will balance the incremental costs of reducing carbon emissions with the incremental benefits of reducing climate damages.

3.3 The SDR in Practice around the World

Since there is no consensus as to which approach is the most appropriate for the choice of an SDR, it is not surprising that there are significant variations in public discount rate policies in different countries around the world. This section provides a survey of the SDR policies in practice used by selected countries and by MDBs.

3.3.1 Practice in Selected Countries

A survey of SDR policies of individual countries around the world show significant variations. Even within a country, different government agencies may have their own policy. Table 3.3 below summarizes the discount approaches and rates adopted in selected countries.

Country/Agency	Discount Rate	Theoretical Basis
Australia	1991: 8%; current: SOC rate annually reviewed	SOC approach
Canada	10%	SOC approach
People's Republic of China	8% for short and medium term projects; lower than 8% rate for long-term projects	Weighted average approach
France	Real discount rate set since 1960; set at 8% in 1985 and 4% in 2005	1985: To keep a balance between public and private sector investment 2005: SRTP approach
Germany	1994: 4% 2004: 3%	Based on federal refinancing rate, which over the late 1990s was 6% nominal; average GDP deflator (2%) was subtracted giving 4% real
India	12%	SOC approach
Italy	5%	SRTP approach
New Zealand (Treasury)	10% as a standard rate whenever there is no other agreed sector discount rate	SOC approach

continued on next page.

Table 3.3 continued.

Table 3.3 The SDRs in Selected Countries		
Country/Agency	Discount Rate	Theoretical Basis
Norway	1978: 7% 1998: 3.5%	Government borrowing rate in real terms
Pakistan	12%	SOC approach
Philippines	15%	SOC approach
Spain	6% for transport; 4% for water	SRTP approach
United Kingdom	1967: 8% 1969: 10% 1978: 5% 1989: 6% 2003: 3.5% Different rates lower than 3.5% for long-term projects over 30 years	SOC approach until early 1980s; thereafter SRTP approach
US (Office of Management and Budget)	Before 1992: 10%; after 1992: 7%	Mainly SOC approach with the rate being derived from pretax return to private sector investment Other approaches (SPC, Treasury borrowing rates) are also mentioned
US (Congressional Budget Office and General Accounting Office)	Rate of marketable Treasury debt with maturity comparable to project span	SRTP approach
US (Environmental Protection Agency)	Intragenerational discounting: 2–3% subject to sensitivity analysis in the range of 2–3% and at 7%, as well as presentation of undiscounted cost and benefit streams Intergenerational discounting: presentation of undiscounted cost and benefit streams subject to sensitivity analysis in the range of 0.5–3% and at 7%	

GDP = gross domestic product, SOC = social opportunity cost, SPC = shadow price of capital, SRTP = social rate of time preference.
Source: Zhuang, et al. (2007).

In North America, Canada uses a rate of 10% based on the SOC approach, while in the US, the situation is more complicated. The US Office of Management and Budget (OMB) uses a discount rate that approximates the marginal pre-tax rate of return on private investment, thus following the SOC approach. In the 1970s and 1980s, it was specified at 10%. In 1992, OMB revised the discount rate to 7% (OMB 2003). The OMB also takes the view that the SPC discounting is “the analytically preferred means of capturing the effects of government projects on resource allocation in the private sector.” In its Circular A-94, OMB indicates that the Treasury borrowing rates should be used as the discount rate in CEA, lease-purchase analysis, internal government investments, and asset sale analysis.

The US Congressional Budget Office and the General Accounting Office (1991) favor the use of discount rates based on government bond rates (Lyon 1990, Hartman 1990). They use the interest rate for marketable Treasury debt with maturity comparable to the program being evaluated as a base case discount rate for cost-benefit analysis, thus favoring the SRTP approach.

The US Environmental Protection Agency (EPA) supports using the SRTP approach in evaluating environmental projects (EPA 2000). It recommends that for intragenerational discounting, a rate of 2–3% be used, which is reckoned to be the market interest rate after tax. The EPA further recommends undertaking sensitivity analysis of alternative discount rates in the range of 2–3% as well as at 7% (prescribed by OMB), as this may provide useful information to decision makers. In addition, all analyses are required to present undiscounted benefit and cost streams. For intergenerational projects or policies with intergenerational effects, the EPA prescribes that economic analyses should generally include a “no discounting” scenario by displaying undiscounted cost and benefit streams over time. The economic analysis should also present a sensitivity analysis of alternative discount rates, including discounting at 2–3% and 7% as in the intragenerational case, as well as scenarios using rates in the range of 0.5–3% as prescribed by optimal growth models. The discussion of the sensitivity analysis is required to include appropriate caveats regarding the state of the literature with respect to discounting for very long time horizons.

In Europe, there is now a near convergence among official SDRs (Evans 2006). Germany uses 3%, based on values of real long-term government bond rate. Norway has been using a 3.5% discount rate after 1998—

also based on real government borrowing rate. France's Commissariat General du Plan in 2005 lowered its project discount rate to 4% based on the SRTP approach. Italy uses the SRTP approach to derive a 5% discount rate, while Spain adopts 4–6% for different sectors.

The UK government indicates in the *Green Book, Appraisal and Evaluation in Central Government* (HM Treasury 2008) that an SRTP of 3.5% should be used to discount future benefits and costs of public projects with a lifespan below 30 years. This figure is calculated on the basis of the estimates of the following three parameters: (i) the rate of pure time preference at 1.5%; (ii) the elasticity of the marginal utility of consumption at around 1; and (iii) the output growth per capita over the period 1950–1998 in the UK at 2.1%. For projects with very long-term impacts (over 30 years), the discount rate will depend on the length of their lifespan: 3.0% for projects with a lifespan of 31–75 years; 2.5% with 76–125 years; 2.0% with 126–200 years; 1.5% with 201–300 years; and 1.0% with 301 years and beyond.

In Asia, the SDRs adopted are generally higher. The Philippines and Pakistan use 15% and 12%, respectively, both based on the SOC approach. India currently uses 12%. In the People's Republic of China, according to National Development and Reform Commission and Ministry of Construction (2006), the economic cost of capital is a weighted average of social time preference and returns on capital. The former is estimated to be around 4.5–6% and the latter around 9–11%. The suggested SDR is 8% for short- and medium-term projects. The document also recommends that a lower than 8% discount rate be adopted for projects with a long time horizon. In Australia, the mandated discount rate was 8% before 1991 and, since then, there has been no prescribed benchmark SDR on the basis that the appropriate discount rate may vary from one year to another, and should be under continuous review. The New Zealand Treasury has a long-standing discount rate of 10%, which was reaffirmed in its *2005 Cost Benefit Analysis primer* (Rose 2006).

3.3.2 MDBs and other Supra-National Agencies

The World Bank's *Handbook on Economic Analysis of Investment Operations* provides guidance on how to calculate the SDR (Belli et al. 1998). The handbook states that the discount rate used should reflect

not only the likely returns of funds in their best relevant alternative use (i.e., the opportunity cost of capital or “investment rate of interest”), but also the marginal rate at which savers are willing to save in the country (i.e., the rate at which the value of consumption falls over time, or “consumption rate of interest”). Therefore, the World Bank prescribes the weighted average approach. The World Bank traditionally has not calculated a discount rate but has used 10–12% as a notional figure for cost–benefit analysis. The handbook further advises that task managers may use a different discount rate as long as departures from the 10–12% rate have been justified in the Country Assistance Strategy.

ADB’s policy on the SDR, specified in its *Guidelines for the Economic Analysis of Projects* (ADB 1997), follows the World Bank approach. Although the *Guidelines* state that “economic rates of return differ considerably between sectors and countries”, and “from time to time, an appropriate discount rate for economic analysis should be calculated for each country to compare with the existing practice”, a single minimum rate of 10–12% has been used in practice to calculate the NPV of a project, or to compare with the internal rate of return, for all countries and all projects all the time. ADB would expect to:

- (i) accept all independent projects and subprojects with an EIRR of at least 12%;
- (ii) accept independent projects and subprojects with an EIRR between 10% and 12% for which additional unvalued benefits can be demonstrated, and where they are expected to exceed unvalued costs;
- (iii) reject independent projects and subprojects with an EIRR between 10% and 12% for which no additional unvalued benefits can be demonstrated, or where unvalued costs are expected to be significant; and
- (iv) reject independent projects and subprojects with an EIRR below 10%.

Other MDBs have chosen an SDR more or less in the range similar to those of the World Bank and ADB. In the case of the Inter-American Development Bank, a 12% discount rate is being used as a measure of the economic opportunity cost of capital while the European Bank for Reconstruction and Development uses 10%. The African Development Bank, based on a review of various project appraisal reports, also uses a project discount rate ranging from 10% to 12%.

Among supranational governmental agencies, the European Commission advocates a benchmark discount rate of 5% in real terms for cost–benefit analysis in the case of member countries of the European Union. This is a compromise figure based on market interest rate, cost of capital, and time preference considerations. However, the European Commission encourages member states to provide their own benchmark for the project discount rate, which must then be applied consistently to all projects (see Evans 2006 and European Commission 2006).

In sum, there are significant variations in the SDR policy around the world. Most MDBs apply a rate of 10–12%, following the weighted average approach. Among individual countries, most developed countries follow the SRTP approach and apply much lower discount rates, mostly in the range of 3–7%, with many revising the rates downward in recent years. On the other hand, the three Asian developing countries surveyed (India, Pakistan, and Philippines) follow the SOC approach, and apply a much higher rate, in the range of 12–15%, and the PRC uses 8%.

As shown in Table 3.3, the differences in the SDR policies in practice are due to different analytical approaches followed. The various approaches reflect differing views on how public investment affects domestic consumption, private investment, and cost of international borrowing. At a deeper level, however, the divergence reflects the differences in the perceived marginal social opportunity cost of public funds, and in the extent to which the issue of intergenerational equity is taken into consideration in setting the SDR. Public funds, in general, have a higher marginal social opportunity cost in developing countries than in developed countries for a number of reasons, such as higher scarcity of capital, poorer financial intermediation, greater market distortions, and greater impediments in accessing international capital markets. Intergenerational equity is a newer issue in the public domain of developing countries than that of developed countries. Therefore, it is not surprising to see that developing countries generally use a higher SDR than developed countries.

3.4 Concluding Remarks

The choice of the SDR plays a critical role in cost–benefit analysis and project evaluation, and has been a subject of intense debate for the

last several decades. In a perfectly competitive world without market distortions, the market interest rate is the appropriate SDR. In the real world where markets are distorted, there are four alternative approaches in the choice of the SDR: SRTP, SOC, weighted average of SRTP and SOC, and SPC. Economists have not reached a consensus as to which is the most appropriate.

The difference among the four approaches reflects largely the different views on how public projects affect the domestic economy: whether public investment displaces current consumption, or private investment, or both, and whether benefits of projects are consumed immediately, or reinvested to generate more future consumption (see Table 3.4 below for a summary). In cases of very long-term projects, an additional consideration is intergenerational equity, where the debate has centered on whether or not one should assume a positive pure time preference on the grounds that individuals are “impatient”, and whether a declining discount rate should be used to avoid problems associated with exponential discounting as implied by a constant discount rate. The recent controversy over the Stern Review focuses largely on what discount rate should be used in cost–benefit analysis of policies to control global warming, which impacts on future generations.

There are significant variations in public discount rate policies in practice around the world, with developed countries applying lower rates (3%–7%) than the developing countries surveyed (8–15%). These variations largely reflect different theoretical approaches to the choice of the discount rate followed by various countries. At a deeper level, however, the divergence also reflects differences in the perceived marginal social opportunity cost of public funds that the SDR tries to measure in order to ensure efficient allocation of resources, and differences in the extent to which the issue of intergenerational equity is considered.

What conclusion can we draw from this survey? First, there is no one-size-fits-all solution to the choice of the SDR. Countries differ in economic structure, capital scarcity, stage of financial development, efficiency of financial intermediation, impediments faced in accessing the international capital market, and social time preference. All these factors together determine a country’s SOC, and should be taken into consideration in the choice of the SDR. Second, there is a need for each country to regularly review the appropriateness of its SDR policy in light of changing domestic economic circumstances and international capital market conditions, and to adjust the SDR as necessary. Third, there is

a strong case for considering the equity issue in discounting benefits and costs of intergenerational projects (e.g., those designed to address climate change and other environmental problems) in addition to the economic efficiency issue, as opposed to intragenerational projects where efficiency should be the primary concern. Finally, for MDBs that provide development assistance to developing countries through capital investment, there could be a case for reviewing their decades-old practice of applying a uniform discount rate of 10%–12% to all projects to see whether this practice is still appropriate in a changing world.

Table 3.4 Approaches to the Choice of the SDR

Approach	Implied Assumption	Who Uses It	Method of Empirical Estimation	Major Criticism
Social Rate of Time Preference (SRTP)	Time-invariant Public projects only displace current consumption	Mostly developed countries	Apply “Ramsey formula” with the following parameters: (i) utility discount rate, (ii) elasticity of marginal utility of consumption, and (iii) growth rate of real per capita consumption Approximated by after-tax rate of return on government bonds	Ignores the fact that public investment could displace private investment Choice of utility discount rate involves normative value judgment, and estimation of the elasticity of marginal utility of consumption is sensitive to data and methodology
	Time-declining Public projects only displace current consumption, and discount rate declines over time as uncertainty increases. There is need to consider intergenerational equity.	Mostly academic and policy researchers	Typically estimated through experiments	Leads to time-inconsistent planning

continued on next page.

Table 3.4 continued.

Table 3.4 Approaches to the Choice of the SDR				
Approach	Implied Assumption	Who Uses It	Method of Empirical Estimation	Major Criticism
Social Opportunity Cost of Capital (SOC)	Public projects only displace current private investment	Mostly developing countries	Approximated by pre-tax rate of return on riskless private investments, such as top-rated corporate bonds	Ignores the fact that public investment also displaces current consumption
Weighted Average	<p>Close economy or open economy with foreign capital rationing</p> <p>Public projects displace current consumption and private investment</p> <p>Open economy with upward sloping supply curve of foreign capital</p> <p>Public projects funded by displaced current domestic consumption, displaced domestic private investment, and foreign borrowings</p> <p>Open economy with perfectly elastic supply of foreign capital</p> <p>Displacement of domestic consumption and investments would be small or negligible; the weighted average approach uses a discount rate equal to foreign borrowing rate</p>	Mostly MDBs	<p>Weighted average of SRTP and SOC</p> <p>Weighted average of SRTP, SOC, and foreign borrowing rate</p>	<p>Ignores the possibility that project benefits could be reinvested</p> <p>Determining the weights attached to SRTP, SOC, and international borrowing rate could be difficult</p>

continued on next page.

Table 3.4 continued.

Table 3.4 Approaches to the Choice of the SDR				
Approach	Implied Assumption	Who Uses It	Method of Empirical Estimation	Major Criticism
Shadow Price of Capital (SPC)	Appropriate when public investments displace current consumption and investment and generate not only future consumption, but also future investment		<p>Converts all costs and benefits into consumption equivalents using the SPC. Discount total cost and benefit flows with SRTP to calculate NPV</p> <p>When the effects of displacement and generation of investments are the same, the SPC approach is equivalent to using SRTP as the discount rate</p>	Although considered as theoretically the most attractive approach, practical application could be difficult

MDBs = multilateral development banks.
Source: Zhuang, et al. (2007).

Appendix 3.1

Estimating the SDR Using the Weighted Average Approach¹²

According to the weighted average approach, also known as Harberger approach, the SDR can be expressed as

$$\delta = \alpha SOC + (1 - \alpha - \beta) i_t + \beta SRTP \quad (1)$$

where δ denotes the SDR, i_t is the government's real long-term foreign borrowing rate, α is the proportion of funds for public investment obtained at the expense of private investment, β is the proportion of funds obtained at the expense of current consumption, and $(1 - \alpha - \beta)$ is the proportion of funds from foreign borrowing. SRTP and SOC are measured, respectively, by the rate of real return on savings exclusive of (i_t) and investments inclusive of (r_j). Expressing the weights attached to different funding sources in terms of elasticities of demand and supply of funds with respect to changes in interest rates, equation (1) becomes:

$$\delta = \frac{\sum_i \varepsilon_i (S_i/S_t) i_t + \varepsilon_f (S_f/S_t) i_f - \sum_j \varepsilon_j (I_j/I_t) r_j}{\sum_i \varepsilon_i (S_i/S_t) + \varepsilon_f (S_f/S_t) - \sum_j \varepsilon_j (I_j/I_t)} \quad (2)$$

where ε_s , ε_p , ε_j are elasticities of savings, supply of foreign capital, and private investment with respect to the interest rate. S_i/S_t and S_f/S_t are the shares to the total savings by various groups of domestic savers and foreign savers. I_j/I_t is the investment share of various business sectors.

Using Equation (2) and 1988–1989 data for Papua New Guinea, Harberger and Jenkins (2002) present an example of calculating the SDR, which they call economic opportunity cost of capital. The example assumes that there are four savers groups: households, business, government, and foreign. The assumptions and results of calculations are given in Table A3.1.1.

The real return on savings for each domestic saver group is calculated by removing the respective tax rates from the nominal market interest rate and then removing inflation:

$$\text{Real return on savings } (i_t) = [i_m * (1 - t) - g] / (1 + g) \quad (3)$$

¹² This Appendix draws from Harberger and Jenkins (2002).

Table A3.1.1 Savers by Group

Assumptions	Households	Business	Government	Foreign
Share (S_i / S_t)	33.70%	44.90%	7.80%	13.60%
Elasticity ($\varepsilon_s, \varepsilon_f$)	0.5	0.5	0	2
Nominal market interest rate (i_m)	14.50%	14.50%	14.50%	
Nominal cost of foreign borrowing (i_f)	9.30%	30.00%	0%	18.00%
Tax rate (t_p, t_w)	9.30%	30.00%	0%	17.00%
Rate of inflation (g)	5.00%	5.00%	5.00%	5.00%
Real return of savings (i)	7.76%	4.90%	9.05%	
Real marginal cost of foreign borrowing				12.31%

Source: Zhuang, et al. (2007).

For the foreign savers group, the same procedure is applied as for domestic savers, but with a further adjustment to reflect the effect of additional foreign borrowing on the country's overall borrowing costs. The adjustment involves the elasticity of supply of foreign funds (ε_f) as well as the rate of change in the foreign borrowing cost as the country becomes more indebted—which is assumed to be 0.6 by Harberger and Jenkins.

$$\text{Real marginal cost of foreign borrowing } (i_f) = \{[i_f * (1 - t_w) - g] / (1 + g)\} * [1 + 0.6 * (1 / \varepsilon_f)] \quad (4)$$

The example further assumes that there are five groups of investors or demanders of funds: housing, agriculture, manufacturing, government, and mining. See Table A3.1.2 for the assumptions and calculations.

The real return on investment is calculated by adjusting the nominal pre-tax rate of return on investment for each sector (i.e., the nominal market interest rate) with tax rates and then taking out inflation, using the following formula:

$$\text{Real return on investment } (r_j) = [i_m * (1 - t_j) - g] / (1 + g) \quad (5)$$

Following equation (2), the SDR, which is the economic cost of capital, for Papua New Guinea is estimated at 11.76%.

Table A3.1.2 Investors or Demanders of Funds

	Housing	Agriculture	Manufacturing	Government ¹	Mining
Share (I_j / I_t)	14.40%	17.70%	65.80%	0%	2.10%
Elasticity (ε_j)	-1	-1	-1	0	-1
Nominal market interest rate (i_m)	14.50%	14.50%	14.50%	0	14.50%
Tax rate (t_i)	15.00%	0.00%	30.00%	0%	35.00%
Rate of inflation	5.00%	5.00%	5.00%	0%	5.00%
Real return on investment (r_j)	11.43%	9.05%	14.95%	0%	16.48%

¹ No data was available on the government's share of investment in Papua New Guinea.
Source: Zhuang, et al. (2007).

4. Good Practices for Conducting Willingness-to-Pay Surveys in the Water and Sanitation Sector

4.1 Introduction

The Asia and Pacific region accounts for about 54% (469 million) of the global population without safe drinking water and 72% (1.87 billion) without proper sanitation (ADB, UNDP, and UNESCAP 2010). Even among urban households with access to water supply and sanitation (WSS), many receive low-quality services. Therefore, the WSS sector is one of the priority sectors for investment in the region. Assessing the demand for improved WSS services is a very important step in designing WSS projects. This chapter describes good practices for estimating demand and willingness to pay (WTP) for improved WSS services. Reliable estimates of WTP constitute the basis for assessing effective demand and benefits of WSS services improvements.

WTP values provide crucial information for assessing the economic viability of projects, setting affordable tariffs, evaluating policy alternatives, and assessing financial sustainability. It also aids in designing socially equitable subsidies (Brookshire and Whittington 1993, Whittington 2002a, Carson 2003, Gunatilake et al. 2006, van den Berg et al. 2006). Very often the WTP data gathered in many project preparatory studies is rarely utilized for such detailed analyses, except for calculating economic internal rates of return (EIRR). More importantly, most WTP field surveys—contingent valuation studies—in developing countries have been conducted with inadequate knowledge of theory and have generated poor quality data. Poorly designed and conducted WTP studies may provide misleading information on project feasibility and sustainability.

Field practitioners, often lacking relevant training in economics, misconstrue that WTP can be easily estimated by asking a simple question, “How much would you be willing to pay for improved water supply?” Such a simplistic way of conducting contingent valuation (CV) surveys has produced poor outcomes, which have been at the root of much skepticism on the use of the results of the CV method for policy purposes. Whittington (2002b, 323) notes that “findings of many of the contingent valuation studies are inaccurate and unreliable and that there is a pressing need to improve the quality of CV studies in developing countries.” Thus, the objective of this chapter is to provide a set of guidelines for conducting CV studies in the WSS sector.

From the viewpoint of practical guidance for estimating reliable WTP, Whittington (1988) pioneered the work on the application of the CV method in water services in developing countries. Since then, within the WSS sector alone (not to mention the broader field of environmental economics), much research on the application of the CV method in developing countries has been carried out, improving the overall knowledge base.¹ This chapter distills the knowledge generated on the CV methodology in the last 2 decades and combines that with the authors’ experience in conducting CV studies in developing countries to provide an easily understandable set of guidelines for undertaking CV studies.

The chapter is organized as follows: Section 4.2 provides a brief update on the overall perception of the economics profession on estimating WTP using the CV method. Section 4.3 discusses preparations in planning a CV study and Section 4.4 examines study design issues relating to the sampling strategy, contingent market scenarios, and the survey instrument. Section 4.5 provides guidance during survey implementation. Section 4.6 discusses data management and preliminary data analysis. Section 4.7 describes some analytical procedures to validate the results of a CV study, extract WTP values, and generate information on effective demand and other policy-relevant issues. The final section provides a brief summary of the recommendations and a checklist to examine the quality of CV studies before using WTP estimates for policy purposes. A detailed example of how a WTP survey was conducted in Sri Lanka and how the data was used for estimation is provided in Chapter 5.

¹ Whittington’s papers (1998 and 2002b) are important contributions that focus on the practical aspects of conducting CV surveys in developing countries. Mitchell and Carson (1989) also provide guidelines for CV practitioners, including a list of questions that should be asked by any decision maker who wishes to use the findings of a CV study.

4.2 Use of CV Method to Measure WTP

The contingent valuation (CV) method is a survey-based elicitation technique to estimate WTP values of a good that is not traded in a conventional market.² The CV method is often referred to as a stated preference method, in contrast to revealed preference methods, which use actual revealed behavior of consumers in the market. Under the CV method, the WTP value of a good or service is elicited by directly asking consumers, whereas the revealed preference method estimates WTP by indirectly examining market prices for the good or service in question. The CV method directly asks consumers for their WTP for a non-marketed good under a given condition or a prescribed circumstance. To elicit consumers' WTP values for non-marketed goods, a hypothetical market scenario should be formulated and described to the survey respondents. Thus, the elicited WTP values of a good are “contingent upon” the hypothetical market prescribed in the survey instrument.³

Despite its wide use for practical policy purposes, the CV method's ability to reliably estimate WTP is not universally accepted. While some economists have remained skeptical about the use of direct questioning to estimate WTP, one of the early verdicts⁴ on the soundness of the CV method came from a group of world-renowned economists: Kenneth Arrow, Robert Solow, Roy Radner, Edward Leamer, and Howard Schumann. Their Blue-Ribbon Panel report for the National Oceanic and Atmospheric Administration (NOAA) (Arrow et al. 1993, 4610) states:

“CV studies convey useful information. We think it is fair to describe such information as reliable by standards that seem to be implicit in similar contexts, like market analysis for new and innovative products and the assessments of other damages normally allowed in court proceedings.”

² These non-marketed goods and services include pollution abatement for cleaner air, preserving historical sites, scenic value of the natural environment, water supply, sanitation facilities, reduction of traffic jams, or new vaccines for protecting public health, among other things.

³ The CV method is a survey technique based on economic theory that was originally and is still most widely used in the area of environmental economics to estimate the public's WTP for improvements in environmental quality (Cummings, Brookshire, and Shulze 1986; Mitchell and Carson 1989).

⁴ Mitchell and Carson (1989) also conclude that the CV method can be used to obtain valid valuation information on public goods, but only if the method is applied in a way that addresses the potential sources of error and bias.

The CV method has improved significantly during the last 50 years. One of the pioneers in the field of CV surveys, V. Kerry Smith (2006), argues that CV research has witnessed robust progress, enabling better understanding of consumer preferences, although careful development of survey instruments (through initial preparatory work, focus groups, cognitive interviews, and pre-tests), conscientious implementation of field work, and rigorous econometric analysis that link the data to underlying theoretical models (e.g., utility functions) remain important.

An important reason behind the reservations about the CV method is the potential divergence between responses⁵ and actual behavior. The emerging evidence shows that predictions from “hypothetical” CV scenarios seem to compare well with actual behavior (Cameron et al. 2002, Vossler and Kerkvliet 2003). Griffin et al. (1995) show similar predictable behavior in the case of WSS improvements. Moreover, Choe, Whittington, and Lauria (1996) show that WTP values from a stated preference model (CV method) are as robust as those from a revealed preference model (such as the travel cost method). Smith (2006) contends that the CV method will remain a significant part of efforts to assess consumer preferences for non-market (and new⁶) goods. Adamowicz (2004), Whitehead (2006), and Whitehead and Blomquist (2006) essentially endorse this view and maintain that CV studies remain a key tool in generating data on new or non-market goods and services for policy analysis.

The above excerpts do not mean to assert that doubts regarding the CV method among some economists have completely disappeared. Despite significant improvements in methodology, debate on the ability of the CV method to meaningfully measure WTP continues. The authors’ view on this matter relies on pragmatism, recognizing the fact that practitioners do not have the luxury of waiting to undertake policy analysis until the academic debate is over. The lack of suitable alternative methods⁷ applicable within the resource and time limitations of many project preparatory studies justifies the use of the CV method

⁵ CV questions ask about future actions of the respondents for hypothetical scenarios.

⁶ “New” in the case of WSS refers to different service quality attributes such as number of hours of service, water quality, customer service, and perhaps service provider (private and public provision, for example). These attributes that make the service a new commodity are easily comprehensible to a CV respondent; therefore the potentially excessive hypothetical biases may not necessarily occur in CV studies conducted on WSS.

⁷ Under certain circumstances, some revealed preference methods, such as market data from water vending, avoided coping costs, and avoided cost of illness, may be available to assess the benefits of WSS projects.

to estimate WTP. In this context, the pragmatic approach is to use the CV method meticulously, applying the improved methodology explained here to generate reliable estimates of WTP.

Over the last two decades, the CV method has been used increasingly in developing countries for improvements in WSS services (Whittington 1988). However, applying the CV method in developing countries requires careful adaptation of the method to account for local conditions and cultural differences (Whittington 1998 and 2002b). Whittington (2002b) identifies three major problematic aspects that need to be addressed: poorly crafted CV scenarios (poor study design), poor survey implementation, and failure to undertake a variety of tests to examine the validity of responses to different CV scenarios. The rest of this chapter is largely devoted to addressing these three issues.

4.3 Planning a CV Study

Planning a CV study involves careful thinking to envision the ultimate services the project will deliver. Initial preparatory activities should provide adequate information that will feed into designing a preliminary version of a CV survey instrument. The preliminary CV instrument should have a reasonable CV market scenario that takes into account the specific locality, various WSS sources and conditions, cultural and socioeconomic situation of the communities, as well as the proposed payment mechanism for the service improvement. Then, it should be refined using focus group discussions and pre-testing in the field. This section first describes the preparatory tasks and then discusses specific design issues.

4.3.1 Initial Preparatory Tasks

Initial preparatory tasks are important for creating credible and understandable CV instruments and study design. These include:

- (i) reviewing project-relevant reports including available census data, water utility records on supply conditions, and a map of the study area;
- (ii) teaming up with local institutions for a CV study;

- (iii) scoping during initial field visits;
- (iv) characterizing the existing WSS situation; and
- (v) preparing a sampling framework.

Collectively, these initial tasks will help the analyst conceptualize a good survey instrument and sampling strategy by focusing on what questions should be asked to assess (i) the socio-demographic profile of the consumers and communities involved; (ii) the current water use behavior and existing water sources; (iii) the characteristics of the existing water sources in terms of quality, quantity, and associated expenditures; and (iv) the policies and programs in operation in the study area. Such assessment will help in identifying appropriate CV market scenarios and relevant issues in delivering water to communities. The preparatory tasks need to be implemented simultaneously, but are discussed sequentially below.

4.3.2 Reviewing Relevant Documents

The initial preparation for the study begins with a review of relevant documents. The analyst should have three goals in mind: (i) to better understand the current WSS situation; (ii) to find out how the population is distributed in the study area and where the poor groups are located, while keeping in mind their current water supply conditions; and (iii) to assess available secondary data on population, housing, poverty incidence, and other associated WSS development initiatives. To achieve these goals, the analyst may want to cover three sets of data:

- (i) **Information on current water supply conditions.** This may include demographic profile of the study area, service connections and coverage, existing tariff schemes and subsidies, supply and consumption levels, service quality, and alternative water sources and services.
- (ii) **Geographic distribution of the poor households.** Information on distribution of poor households in relation to the water distribution network will be very useful in designing pro-poor service options. With recent advances in geographical information systems (GIS), location data on the poor can be integrated into maps. Availability of such maps is also of great value to the design of the sampling framework. Any

literature on potential impacts of current and future WSS policy decisions on the poor would also be valuable.

(iii) **Census data and other statistics from secondary sources.**

To understand the overall socio-demographic composition of the study area data can be gathered from local census departments; the Demographic and Health Surveys (DHS) funded by the United Nations Population Fund (UNFPA), United Nations Children’s Fund (UNICEF), and United States Agency for International Development (USAID); the Living Standards Measurement Study (LSMS) of the World Bank; the Family Life Surveys (FLS) by the RAND Corporation; and other special purpose surveys commissioned by government or aid agencies.

4.3.3 Teaming Up for a CV Study

Given that water and sanitation problems are rarely the concern of any one discipline, a multidisciplinary team of collaborators is desirable for the success of a CV study. The following team composition is desirable: an economist with in-depth knowledge and field experience in CV studies, a municipal engineer, a financial specialist, and enumerators for field surveys. The team needs to partner with local collaborators who are experienced in social surveys and handling statistical data in the region or study area.⁸ Through collaboration, in-country participants will be exposed to the latest methods for assessing demand for improved WSS. Besides on-the-project learning and training, in-country participants would be well positioned to argue for improved water services with adequate water tariff adjustments. They also provide local language skills for translating CV instruments and conducting interviews. If local collaborators can provide a statistician for sampling, this additional asset can help improve CV data quality. Essentially, there is an element of capacity building for the local counterparts, and hence, partnering with them will be mutually beneficial.

⁸ Generally, it is beneficial to team up with local academic institutions for CV surveys. In addition to having a large cadre of committed students who can serve as enumerators, these institutions generate goodwill with the local population and provide access to e-mail, library resources, and a community of field-based researchers.

4.3.4 Scoping during Initial Field Visits

Together with in-country collaborators, the analyst should conduct initial scoping visits to the study area. In preparation for the field visits, the analyst should have reviewed available secondary data from the local or provincial level census data, and should bring the available maps (contour map, administrative boundary map, road networks, and even a tourist map, if available) for the scoping exercise. In addition to achieving familiarization with the study area and direct observation of various aspects of water supply and sanitation, the initial field visit should include:

- (i) Discussions with local government representatives regarding the political and technical feasibility of service options for improved WSS provision (Estache et al. [2002] provide a good summary on this aspect).
- (ii) Consultations with nongovernmental or community-based organizations working on WSS in the study area.
- (iii) Conducting rapid appraisals to get an initial grasp of environmental, socio-cultural, economic, institutional, and policy issues across zones and different segments of user groups in the study area.
- (iv) Consultations with randomly chosen households through open-ended interviews and community participatory meetings to better understand the WSS situation in selected communities, and the socioeconomic strata of the study area.

4.3.5 Characterization of the Existing WSS Situation

Regardless of the possible variations in the objectives⁹ of a CV study, characterization of the current WSS situation is the first step in developing suitable CV scenarios. As Whittington (2002a, 83–4) contends

⁹ There can be a wide variation in the objectives of a CV study even though the main goal is to estimate WTP. For example, associated policy analysis may take different forms depending on the situation. CV studies may focus on poverty and affordability, financial sustainability, and other relevant policy issues to different degrees, making them quite different.

(referring to the importance of prior characterization of existing WSS services), preparatory activities help avoid the pitfalls of poorly defined and executed CV surveys:

...we typically collect information on local water markets, observe water collection practices at sources, interview water vendors, conduct unstructured open-ended interviews, hold participatory community meetings and smaller focus groups, and administer in-person interviews with randomly selected respondents. Conducting a structured, in-person interview (for estimating WTP) is only possible after careful, qualitative (prior) work has been completed.

It would be impossible to develop accurate measures of demand without sound understanding of the background WSS situation as the CV surveys are often trying to measure WTP for improvements in WSS. Improvements are defined by taking the current characteristics as a benchmark. Conducting an assessment of the improved services should be accompanied by information on: (i) what people are currently using; (ii) what improvements are feasible from an engineering, economic, financial and cultural perspective; and (iii) how people view the role of water and sanitation in their daily lives. This exercise is essential to gaining a better understanding of the household's choice for the proposed change in WSS services. A thorough and detailed characterization of the existing water and sanitation situation is a prerequisite for conducting policy analysis as well. The aspects that need to be covered in characterizing existing services can vary case-to-case. Regardless of these potential variations, the characterization should generally focus on four aspects of the current situation—physical characteristics, economic factors, environmental health indicators, and institutional features. Additional characteristics should be considered as needs arise.

A. Physical Characteristics

In characterizing current conditions, it will be necessary to understand the water sources currently used by the household as well as alternative sources that can potentially be used. The list usually includes household water supply connections operated by public or private entities, private wells, neighbors, public or private tankers, bottled sources, and a variety of public or “free” sources such as public wells, public taps, rainwater,

rivers, or streams. Available sources can be used to understand the substitution possibilities in the case of a potential tariff increase. For example, Pattanayak et al. (2004a) show that households with reasonably good alternative sources such as wells have low WTP and high rejection rates for improved services. In certain cases, quantitative information on water use from different sources is valuable for policy analysis purposes. Similar details on the types and extent of sanitation alternatives will also be useful. The quantitative information on consumption can be used to estimate the price elasticity of demand, which is very useful in accurately forecasting utility revenues needed to assess financial sustainability.¹⁰ Finally, the analyst needs some measure of the existing water quality. Traditionally, water quality is measured based on household perceptions of color, taste, and health risk. To the extent that perceptions affect behavior, subjective water quality measures are useful. Resources and time permitting, the analyst may consider more objective measures such as microbiological quality, temperature, turbidity, and chemical contamination (e.g., from fluoride or arsenic).

B. Economic Factors

For each WSS alternative, direct monetary costs include utility bills and the household's cost of operation. Households can also have significant indirect or "coping" costs because of inadequate infrastructure services (Choe, Whittington, and Lauria 1996, Pattanayak et al. 2005). Typically, the time spent on collecting water constitutes the greatest share of the coping costs. Second, as part of the assessment of coping behavior, the analyst may gather information on household sanitation and hygiene practices such as boiling, chlorination, filtering, water handling and storage, and hand washing that can mediate the impacts of the WSS. From a policy support perspective, it is critical to collect data on existing tariff and network services for typical households from published reports and papers.

C. Environmental and Health Factors

Some argue that the most significant benefits of water and sanitation services are improvements in public health (Fewtrell et al. 2005, Bosch

¹⁰ Nauges and van den Berg (2006) used the consumption and other data of Pattanayak et al. (2004) to estimate a demand price elasticity, which helped the analysis of tariff setting and financial sustainability.

et al. 2000). A meta-analysis suggests that water, sanitation, and hygiene interventions may generate significant gains in health, reducing the incidence of diarrhea by approximately 30% among children in developing countries (Fewtrell et al. 2005). These impacts can be analyzed by collecting data on at least three interrelated factors. First, the analyst would need information on the main forms of waterborne and water-washed health risks in the study area. This information can be gathered from secondary sources and the survey. Second, the analyst can collect data on recent illnesses including details of disease incidence associated with poor quality WSS, such as morbidity and mortality events, medical costs, and lost work days. Third, as part of the validity tests, the analyst can check whether households that have experienced water-related diseases have a higher WTP.

D. Institutional Factors

Another important feature of the existing situation includes the institutional and policy variables affecting households. Community surveys can be used to elicit information on institutional data including the existence of registered user groups, the vitality of such community initiatives, programs for metered standpipes, and cost-sharing schemes. On many occasions, CV studies are undertaken prior to privatizing water utilities. In order to gather the preference of consumers on the institutional provision of the service (public, private, or community managed), different CV scenarios may need to be administered. In characterizing the current services, the analyst can get some initial insights through focus group discussions and open-ended or semi-structured interviews.

Information on the existing WSS situation should be first assessed using field observations, semi-structured interviews, interviews of key informants and government officials, and small focus group discussions. This information should then be used to initially characterize the existing services to help design CV scenarios. In addition, this characterization should help in formulating the questions to generate a set of data that formally describes the existing situation through the structured survey. Overall, characterization should provide the analyst with a good overview of the WSS situation and help understand the specific cultural contexts. The information initially collected through the above-described activities is useful in designing policy and gauging the findings of the CV study against the real WSS situation.

4.3.6 Preparing a Sampling Framework

During the initial preparation stage, the analyst should investigate the potentially feasible sampling frameworks. A sampling frame is a list of possible members of the population of interest, from which respondents for the study (generally households) will be drawn. Selection of a representative sample is very important to ensure that sample findings can be generalized to the whole population with a degree of confidence. In developed countries, the sampling framework could be the local telephone directory, social security numbers registered in the study area, or driving licenses, for instance.

However, in the context of a developing country, such comprehensive and detailed listings may not be available. Sometimes a population census may have a list of households that can be updated as a sampling frame. On other occasions, the analyst may find lists of households maintained by community leaders. If such listings of the study population are not available, then a map can be used to achieve a pseudo-random sampling framework. If the team decides to use the map as the sampling framework, then understanding the geographical distribution of overall water users by market segment (by average income levels of communities, individual versus public tap users, or distribution networks) is essential in designing a geographic sampling method. The initial preparatory work should provide the basis for the study team to decide on the appropriate sampling frame.

4.4 Study Design Issues

Upon completing the prescribed preparatory tasks, the analyst can proceed with the actual design of the CV study.¹¹ Key issues in designing a CV study are discussed below.

4.4.1 Designing the Sampling Strategy

Sampling entails: (i) defining the population, (ii) specifying the sampling frame, (iii) selecting the sampling method, (iv) determining the sample

¹¹ It should be noted that this section is prepared largely to guide practical field work; for greater detail, see Dalenius (1985).

size, and (v) specifying the replacement strategy for non-responding households.¹² The sampling design generally starts with identification of the study population. In a WSS sector project preparatory study, the population consists of the potential beneficiaries of the proposed project. Once the population is known, the next step is to define the sampling frame. A good sampling frame should be reasonably representative of the study population and allow sufficient representation of subgroups of special policy interest (Deaton 1997). The best source of information in developing a sampling frame varies from country to country. The analyst must identify proper ways to physically identify the elements of the sampling frame in order to carry out the survey.

After determining the sampling frame, the analyst must decide on the sampling method in order to select the sample randomly from the sampling frame. There are two approaches to sampling: probabilistic and non-probabilistic sampling. Of these two, probabilistic sampling is preferred as it allows proper application of systematic statistical inferences, which in turn permits generalizing the sample findings to the entire population.

A. Sampling Strategies

Sampling strategies depend on various factors, such as how many variables should be analyzed in the CV study, or how many sub-segments of water users exist, and their geographic distribution across the study population. Strategies may include simple random sampling, stratified random sampling, cluster sampling, and quota sampling. Of these strategies, stratified random sampling is the most widely used method in CV studies.

When the population embraces a number of distinct categories, the sampling frame can be organized by these categories into separate strata (for example, communities with individual connections versus those without). Sample households are then randomly selected from each stratum separately, producing a stratified sample. There is no general rule to guide the selection of strata as it is situation-specific. However, the statistical properties of the strata should ensure that the means of inter-strata variables should be substantially different; and that there exists a minimum variance within a stratum as well as a maximum variance among

¹² In CV studies of WSS projects, the household is normally the sampling unit, so its response is the single data point to be observed.

strata. In a WSS study, typical strata may include different geographic areas or administrative units such as districts or communes, connected and unconnected households, and different income groups. Information collected through initial preparatory work is useful in identifying and selecting suitable sets of strata. Once the analyst has decided on the strata, a representative sample from each stratum should be randomly selected. This can be accomplished by using random number tables.¹³

B. Staged Sampling Process

While the stratified random sampling method generally provides a suitable approach for sampling in CV studies, under certain circumstances the analyst may apply another stage of stratification (where the upper level sampling unit becomes a cluster). When the number of clusters (such as the boundaries of communities or small districts within the study) are large, there is no compelling reason to include all the clusters; and where the budget and other constraints do not allow inclusion of all the clusters, the analyst may first select clusters randomly. Once the clusters are selected at the first stage, then the sample households are randomly selected within each chosen cluster. This procedure is known as stratified two-stage random sampling because it involves sample selections at two stages, first at the cluster level, and second at the household level.

This procedure may be further extended to three-stage or multi-stage sampling. If the sampling strategy involves stratified sampling, proportional representation of sample strata should be checked against that of the study population. The effectiveness of the stratification depends on the accuracy of prior information about the distribution of the overall population by location, socioeconomic status, or other dimensions of special interest in a particular study. While undertaking the preparatory tasks, the analyst should keep in mind the information requirement for developing a suitable sampling method. The choice of the strata should be guided by both the specific objectives of the study and the characteristics of the study population.

C. Sample Size

The size of the sample depends on: (i) whether the elicited WTP values are based on a “referendum” question or an “open-ended” question, (ii) how many versions of the contingent market scenario will be

¹³ Kalton (1983) gives a simple and practice-oriented discussion of sampling.

administered, (iii) how many stratifications are used for sampling, (iv) what is the acceptable margin of statistical error ranges in WTP values, (v) the number of independent variables determining WTP values, and (vi) the available budget and time limitation to complete the CV study. The size of the study population is an important element to consider, even though it is not the only key determinant of sample size. Appendix 4.1 shows how sample size can be determined based on the size of the population. On one hand, the sample size can be calculated according to the number of CV versions to be tested. The number of bids offered in a CV scenario is also an important determinant of the sample size since each bid should be administered to a minimum number of households. The final decision on the sample size is also determined by the study budget.

For instance, suppose a CV study is designed by factoring in: two stratifications (individual tap connection versus no taps), five bid values to estimate WSS demand, and two versions of the CV scenarios to test (public provision versus public-private partnership [PPP]). Then, the total sample size required for statistical analysis becomes 600 households (equals $2 \times 5 \times 2$ multiplied by 30 households in each cell).¹⁴ If the calculated sample size is too large given the budget, then the analyst should adjust the original decision by tracing back and considering: what is the feasible sample size given a particular budget and time, which of the determinant factors should be redesigned¹⁵ to reduce sample size to fit the resource limitations, and therefore, what would be the optimal sample size without sacrificing the reliability of the statistical inference.

D. Random Selection

Once the analyst obtains a household listing, devises a sampling strategy, and determines the sample size and sub-sample size from each stratum, he/she should randomly select the specified number of households. These selected households will constitute the survey sample and should be contacted by the enumerators. Randomization, efforts to locate the selected households, and interviewing them are all very important steps that sometimes do not get adequate attention in many surveys.

¹⁴ Here, the number 30 is a general rule of thumb to protect statistical degrees of freedom in estimating a demand function. If the clusters include mutually exclusive variables of importance, the sample size will increase substantially.

¹⁵ For example, if the analyst has adequate information to decide that WSS should be privately provided, the sample size can be reduced to 300.

Close supervision of enumerators is critical to ensure that enumerators interview the sampled households, not others at their convenience. In many developing countries, contacting the households to make prior appointments by telephone or e-mail may not be possible. Therefore, enumerators just walk over to the households to get their consent for the interview. Also, access to households may be difficult because the postal address is not clearly marked for each building, and households may want the enumerator to visit at another time. Under such circumstances, enumerators tend to go to households that were not selected as part of the sample. This practice should be prevented through strict and continuous supervision during survey implementation.

In some developing countries, complete lists of households that can serve as a sampling frame are not available. Even if such listings are available, it is not easy to locate them as explained above. Under such circumstances, the analyst may use a map as a sampling framework, rather than search for a complete listing of households. To do this requires, first, creating cells or clusters by drawing grid lines over the map and numbering each cluster. Second, it requires using a random number table, selecting the number of clusters where enumerators for the survey will be deployed. Third, enumerators should be instructed to go through the neighborhood in a consistent manner with a clear rule for selecting houses within the selected cluster. A common practice is to select every 10th house on a given street. Access to selected households may be difficult as households sometimes decline to be interviewed. In such cases, the enumerators should implement a pre-selected replacement strategy to maintain the random sampling process (see Section 5.3.1 in Chapter 5 for an example).

4.4.2 Designing Contingent Market Scenarios

Seven guidelines for designing CV surveys were developed by the NOAA Panel, also known as the “Seven Pillars of NOAA” (Arrow et al. 1993, Portney 1994). The Panel suggests the following practices when designing CV surveys:

- (i) Interview in person rather than over the telephone.
- (ii) Question about a future hypothetical occurrence rather than a historical event.

- (iii) Use a referendum format (as opposed to open-ended questions) in which the respondent “votes” on a benefit with a known price.
- (iv) The interviewer should begin with a scenario accurately describing the benefits of a contingent market commodity.
- (v) The survey should point out that payment for the new commodity may reduce consumption of other goods.
- (vi) The survey should point out that substitutes exist for the hypothetical commodity in question.
- (vii) There should be follow-up questions to make sure the respondent understands the choices made.

These guidelines, together with other considerations below, are recommended as best practice in designing CV studies.

A. Commodity Definition in the CV Market

Lack of adequate attention to precisely describing the commodity in question is one of the reasons for unreliable WTP estimates. The description of the commodity or scenario development primarily involves: defining precisely the type of WSS services offered, clarifying how it differs substantively in quantity and quality from current options, and explaining the institutional setting for providing the service. Identifying and defining the appropriate commodity requires a careful review and thorough understanding of existing levels of service and alternatives in the study area. Information collected prior to the survey for characterizing the WSS situation will be useful in defining the commodity. For example, if preliminary evidence suggests that a certain percentage of the population is connected to the piped water network, the commodity in question can be “an improvement in existing services” for this sub-sample, in contrast to “a new service connection” for unconnected households. These two subgroups need different CV market versions as well as elicitation questions, because unconnected households need to pay a connection charge in addition to the bills for water consumption.

In general, the preparatory activities and focus group discussions can uncover important features of the selected service options such as use of meters, hours of supply, and water quality. In the case of project preparatory CV studies, where improved service delivery design may already be available, the commodity should be described as it is

planned to be offered by the project. However, if certain elements of the scenario, based on the initial qualitative assessments, are expected to substantively affect household demand for improved services, those elements can become design features that vary across the surveyed households. For example, households may have different preferences for the alternatives of private sector provision, reformed public sector, or community provision, despite the fact that the original project idea is to provide the service through the private sector. If the privatization process is viewed as a polarizing feature of service provision, the analyst could define different versions of the commodity corresponding to private, public, or community providers of improved services. Surveys with these different versions would be administered to different subsamples, and econometric modeling should be used to detect whether the private versus public institutional context affects household demand and choice. The following is an illustrative definition of a commodity:

Suppose your household receives 24-hour water supply service (reliability), with water that is safe to drink from the tap (quality), accurate billing of the water with reliable and responsive customer service (customer service quality) by a private service provider (service provider). But your household would have to pay higher water bills (payment mechanism, cost).

Note that the commodity is defined precisely with a number of attributes such as reliability, water quality, customer service quality, service provider, payment mechanism, and cost before asking whether the respondent is willing to pay a given amount to get the improved service. This detailed and clear definition of the commodity reduces the cognitive demand on the respondent in synthesizing an answer to the elicitation question. Moreover, this type of precise definition makes it easier for the respondent to compare the improved service with the existing service before accepting or rejecting the proposed CV scenario. Many CV surveys in developing countries have failed to provide an accurate definition of the commodity in question. Asking people's WTP without properly describing the commodity for which they are expected to agree to pay defeats the purpose of the CV survey. Therefore, commodity definition is a very important aspect that needs to be improved in future CV studies.

B. Payment Method

The payment method or the payment vehicle—how individuals are asked to pay for the services—is also an important design issue in CV studies. In certain CV studies that deal with unfamiliar goods such as biodiversity protection or prevention of climate change, the payment vehicle (for example, a voluntary contribution or a tax) could be a potential source of hypothetical and other biases. In the WSS sector, this is of lesser concern because payment vehicles such as water bills and connection charges are familiar.¹⁶ The usual approach is to ask the valuation question from an *ex ante* perspective in the form of increments to current bills or new bills. For households that are already connected to the WSS system, the elicitation question would target the maximum amount the household would pay in addition to current monthly bills to have the improved service.¹⁷ For households without a connection, the payment method may be a connection charge plus monthly bills. Water bills and connection charges generally serve as reasonable payment vehicles, particularly in study areas where they already exist.

C. Elicitation Method

CV elicitation questions can be of two basic forms: open-ended or closed-ended. In an open-ended question, the respondent is asked to state the maximum amount that he/she is willing to pay for the good that is being valued. Open-ended questions provide more information than closed-ended questions, and do not require econometric modeling¹⁸ to analyze, as the mean WTP values of respondents can be readily estimated by simple arithmetic. However, answering an open-ended question on a new commodity requires a higher level of cognitive demand on the part of respondents, because individuals are typically not accustomed to making such decisions in daily life. Open-ended questions also lead the respondents to base their answers on their knowledge of the cost of providing WSS and sometimes on their political beliefs, such as

¹⁶ However, if one administers a CV study in a community that has never paid water bills, using the bill as the payment vehicle can cause considerable hypothetical responses. Moreover, if the community is politically charged against water billing and considers water as a free good, using it may result in a higher number of protest responses.

¹⁷ The authors' experience suggests that sometimes the incremental increase can confuse the respondents. If such evidence is detected in the focus group discussions or pretests, the question can focus on the monthly bill for the improved services.

¹⁸ Some authors consider the requirement to undertake econometric analysis as a barrier to the use of the closed-ended elicitation method, however given the availability of user-friendly econometric packages it is no longer a barrier.

whether water should be free of charge. Such type of anchoring may underestimate the true benefit of WSS. Moreover, validity testing, which is vital to provide credibility to WTP estimates, still requires econometric modeling.

In view of the above, a closed-ended approach is preferred to elicit WTP for improved WSS services. With a closed-ended CV question (also referred to as a “dichotomous choice” or “referendum” question), the respondent is asked whether he/she is willing to pay a specified amount presented as the value of the improved service. The respondent is expected to answer “yes” or “no.” Closed-ended questions have been the preferred form of elicitation question since the approach was introduced by Bishop and Heberlein (1979). Researchers¹⁹ frequently recommend the dichotomous choice method (Portney 1994) and its application in WSS projects has provided reliable results so far (Pattanayak et al. 2006). This method enables the prediction of demand with respect to changes in prices and income and that provides an added advantage in project preparatory studies.

Other elicitation questions—which are largely some modification of the open-ended and closed-ended questions—include iterative bidding questions, contingent ranking questions, and the payment card method. Choosing among the various options is difficult as neither economic theory nor empirical evidence provides clear guidelines in selecting elicitation questions. A summary of the strengths and weaknesses of different elicitation is provided by Boardman et al. (1996). We recommend the closed-ended format given emerging evidence and considering the added advantages described above (see Appendix 4.2 for strengths and weaknesses of different elicitation methods).

D. Bid Distribution

In the closed-ended format, the household is presented with a specific amount as an increment to the bill or a new bill. The elicitation question asks whether the respondent is willing to pay the specific amount to acquire the improved service. In order to facilitate the econometric modeling of the responses, a range of values (bids) will be presented to different households. It should be noted that each household will only be asked to respond “yes” or “no” to a single bid. The bids will be randomly

19 For example, as noted above, the US NOAA Panel, appointed to evaluate the appropriateness of CV methods to design compensations for environmental damages, recommended the dichotomous choice method.

allocated among the households. For example, if the sample is 1,000 and there are 10 bids, each bid will be presented to 100 households.

Selection of the bids may have some influence on the WTP values, because respondents may refer back to these initial values in answering the CV question. A number of factors should be considered in deciding the range of bids. They should be realistically close to the actual costs and current bills. If some prior knowledge is available on future tariff increases, these new rates should be within the range of bids. The ranges of the connection charge and monthly bill should be sufficiently wide to assess demand and to capture relevant policy alternatives. The number of bids included in the study is usually dictated by the study budget because more variation in the bids requires larger sample sizes. Moreover, too many bids and too large samples may also be logistically challenging during survey implementation. Typically, background information and focus group discussions would help determine the range of the bid values. The rule of thumb is that the lowest bid should be low enough that most of the respondents will accept it, while the highest bid should be high enough that most respondents (90–95%) will reject it (Whittington 1998). The same rules apply to the connection charge.

4.4.3 Designing the Survey Instrument

Survey instruments vary from study to study depending on the specific context. In general, a survey instrument should have the following modules:

- Module I: An introductory section, briefly describing the background and purpose of the survey
- Module II: Questions on the demographic and socioeconomic profile of the households, and the socioeconomic profile of the respondents interviewed
- Module III: Questions on current water supply conditions and consumption behavior
- Module IV: CV market scenarios followed by questions eliciting WTP values
- Module V: Debriefing questions

Module I introduces the purpose of the survey, seeks the consent of respondents for the interview, and instructs respondents on the interview procedure. All interviews must comply with government regulations on human rights protection, and must be consistent with survey research protocol for seeking consent, ensuring confidentiality, and minimizing risk to respondents.²⁰ The first module should include household identification numbers, cluster identification (if cluster sampling was used), and contact address for follow-up information, if need arises.

Module II focuses on compiling basic social, demographic, and households' economic information, such as family size, education, occupation, number of income-earners, asset ownership, income levels, and expenditure patterns. Also, this module clearly identifies which member of the family responded to the survey (or more precisely, checks that the interview is consistently administered with a household head), and gathers socioeconomic information on that particular respondent, including age and gender. The analyst should ensure that the survey instrument includes the set of variables needed to estimate a WTP function and to carry out validity tests (see Section 4.7.1). Basic household information is important at a later stage in analyzing what factors influence WTP values for improved WSS services, thus informing subsequent policy discussion.

Module III focuses on current water supply situations, consumption patterns, and use behavior. This involves eliciting information on existing physical conditions; water sources, associated quality (taste, odor, safety, regularity); estimated consumption volumes; any supplementary equipment used by individual households; time and money invested to improve existing water conditions; reliability of water meters; and monthly bills. It is important to collect information on both primary sources and alternative sources available in the community that may not be used by the household, such as public piped water, water vendors, public or private trucks, bottled sources, standpipes, wells, and rivers. After presenting the characterization question, the same module may ask about averting and mitigating activities such as boiling, chlorination, filtering, and hand washing, as well as household coping behavior in general, such as time spent walking to and waiting at public sources, pumping, and storing in a tank.

²⁰ See Whittington (1998 and 2002b) for discussions of ethical problems in conducting CV surveys in developing countries.

Module IV describes the CV market scenario before eliciting the WTP values. As discussed previously, the improved service should be described prior to asking the elicitation question. The questions in the third module thus should be a platform for the respondents to compare what the current WSS situation is and what it would be like with the improved services. This recollection process is important because having a meaningful comparison of the current situation with the precisely defined new service enables the respondents to provide truthful answers to the elicitation question. The CV market scenario should be written and every enumerator should be instructed to read the same CV market information to all the interviewees consistently. After this, the enumerator can administer the elicitation question. See Appendix 5.1 in Chapter 5 for an example of clearly written scenarios and elicitation questions.

Module V seeks to further verify why a particular response is given to the WTP elicitation question. Here, the respondent is given an opportunity to further explain the “yes” or “no” answer to the elicitation question. Asking this follow-up question to the respondent who said “no” to the elicitation question is of particular importance. If a respondent provides an answer such as “my family income is not enough to pay for the improved services” or “I am happy with my current service”, this implies that the respondent has provided a reasonable “no” answer. On the other hand, if a respondent says “I don’t know” as the reason to answer “yes” or “no”, this is cause for concern, as it implies that the respondent may not have understood the question or may not have thought it through properly before answering the CV question. In such cases, going through the elicitation questions once again may lead to different answers. If the respondent repeatedly provides a similar vague response as the reason for their answer, this particular respondent should be dropped and the replacement strategy has to be used to interview another household. If a “yes” answer cannot be supported by a valid reason as well, that response cannot be considered reliable. Properly designed debriefing questions thus provide an on-site validity test for the responses given to the elicitation questions. Sometimes, a “yes” answer will be followed by “but I cannot afford to pay the bill.” This should be interpreted as “no”. Whittington (1998) explains how the respondent may say “no” politely according to certain cultural norms, while starting with a “yes.”

The preliminary instrument should be constantly modified throughout the design stage, based on the findings of: (i) the scoping

visit, (ii) rapid appraisals, (iii) meetings with key informants, (iv) focus group discussions, and (v) semi-structured interviews, as well as during the training of enumerators. The recommendation to collect data in addition to CV responses is primarily for validation of the CV responses and the WTP estimates derived from the responses. CV responses must be correlated with theoretically appropriate variables such as income and water scarcity. Similarly, CV responses and WTP estimates must be correlated with and comparable to indicators of demand for WSS revealed through coping, averting, and other “revealed preference” data whenever possible. CV studies in developing countries have used questionnaires with varying degrees of quality. Many of the questionnaires administered in such studies have missed some of the important elements described above. Therefore, paying more attention to the questionnaire is necessary to improve the quality of future CV studies. Table 4.1 summarizes a number of good practices that can be used in designing CV studies in the WSS sector.

Table 4.1 Recommended Good Practices for Designing CV Water Studies

Design Issue	Recommended Good Practices
Commodity Definition	<ul style="list-style-type: none"> • Precise definition including reliability, water quality, customer service quality, service provider, and cost
Elicitation Method	<ul style="list-style-type: none"> • Closed-ended (referendum) format
Payment Vehicle	<ul style="list-style-type: none"> • Connected households: water bill • Unconnected households: connection charge and water bill
Survey Method	<ul style="list-style-type: none"> • In-person interviews
Sampling Method	<ul style="list-style-type: none"> • Stratified random sampling or cluster sampling together with proper description of sampling frame and strategy together with a replacement strategy
Sample Size	<ul style="list-style-type: none"> • Adequate sample size based on the size of population (refer to Appendix 4.1), number of CV scenarios, number of bids, number of anticipated split samples
Survey Instrument	<ul style="list-style-type: none"> • Should include (i) an introductory section; (ii) socio-economic profile of the respondents; (iii) a detailed description of the commodity; (iv) a proper elicitation question; and (v) debriefing questions. • Focus group discussions and pre-testing before finalizing the instrument.

continued on next page.

Table 4.1 continued.

Table 4.1 Recommended Good Practices for Designing CV Water Studies	
Design Issue	Recommended Good Practices
Reporting	<ul style="list-style-type: none"> • Should provide adequate information on the preparatory activities to understand and make a judgment about the quality of the CV survey design
CV = contingent valuation. Source: Gunatilake, et al. (2007).	

4.5 Survey Implementation

4.5.1 Survey Administration

The manner in which the survey is administered is important. As suggested by the NOAA Panel, in-person interviews are the most desirable approach, as opposed to mail-out or telephone surveys. In developing countries, households are often very cooperative in face-to-face surveys; rejection rates of participation are usually low; and the costs of in-person surveys are not prohibitive. With the increasing availability of computing technology, computer-assisted surveys have become feasible and offer a great advantage in the reduction of data entry and quality assurance costs.

A CV survey is usually implemented through four interrelated sub-tasks: (i) enumerator training, (ii) focus group discussion, (iii) pre-testing, and (iv) supervision of survey implementation. Each of these sub-tasks is discussed in the following section. Before the implementation of the field survey, it is good practice to review the measures taken to minimize potential biases in the study. Once the survey proceeds and pitfalls are discovered during survey implementation, the integrity of the whole sample may be compromised, thus requiring a completely new sample for a fresh start. Appendix 4.3 discusses different biases and the measures to minimize or avoid these.

4.5.2 Enumerator/Field Coordinator Training

Enumerator training plays a crucial role in ensuring CV survey quality. Whittington (2002b, 345) stresses the importance of training enumerators

for CV surveys:

“The goal of the CV researcher is to gauge the attitudes and perceptions of a study population and to listen carefully to respondents’ voices. The messages from the respondents to the researcher are filtered through the enumerators. Unless enumerators are well-trained and committed, it is next to impossible for the CV researcher to accomplish her objective.”

Well-trained enumerators and field coordinators are critical to the quality of any survey data.²¹ First, enumerators and selected field coordinators should be thoroughly familiar with the survey instrument such as the intricate details of each module and the skip patterns built into the questionnaire. Second, training sessions serve as an additional focus group discussion to help the analyst refine the wording and flow of the questions. Third, proper training of enumerators is essential in minimizing some of the potential biases in the answers. This section summarizes briefly the essence of enumerator/field coordinator training.²²

The training can include a mix of lectures, role playing, and field trials. Lectures over several days will introduce the enumerators to the basic concepts of the CV method and the valuation of non-market goods, economic concepts underlying the CV method, and the importance of skillful communication when asking sensitive information such as on income and expenditure. The training should also cover details of data entry with consistent recording of the unit of measurement; treatment of differences (between zero value, don’t know answer, no answer, or decline to answer); and consistent use of terminology throughout the survey as well as across enumerators. Role playing and mock interview sessions are likely to generate the most intensive learning.

Finally, training in field settings, including practice interviews with households, allows the enumerators to get a feel for the study area and the actual interview process. The pre-test, as described below, is part of the final training. Using similar methods, all field coordinators need to be trained separately regarding the supervision of enumerators and the conduct of community surveys. A sample training agenda is shown below.

²¹ It is good practice to create a team of 4–5 enumerators, one of whom is nominated as the field coordinator. The selected field coordinator will coordinate drop-off/pick-up points of daily field work, and monitor the team members’ whereabouts. Every questionnaire should be certified by the field coordinator for accuracy and completeness before submission to the local team leader.

²² See Whittington (2002b) for more detail.

Due to the complexity and variability of CV studies, the analyst should treat this list only as a basic guide and feel free to add more aspects to the training module depending on the specific needs of the study.

- (i) Discuss the purpose of the study.
- (ii) Review the structure of the survey instrument.
- (iii) Illustrate how survey data will be used in the final analysis.
- (iv) Review the structure and purpose of the CV method.
- (v) Explain the challenge of presenting hypothetical scenarios in a credible way.
- (vi) Conduct mock sessions in which enumerators administer the entire survey to each other.
- (vii) Explain ground rules for conducting CV surveys (see Appendix 4.4).

4.5.3 Focus Group Discussions

Brainstorming sessions with a few focus groups are an integral part of survey design. They help in securing information for developing the questionnaire prior to its implementation and refining the design features of the CV questions (Rea and Parker 1997). Focus groups generally involve 8 to 15 participants from different segments of the target population,²³ using segmentation criteria such as the type of WSS user, employment and socioeconomic status, age, and education. Participants will be provided with information regarding the nature and content of the study. Group discussions should center on their opinions, perceptions, and reactions to this information. Responses from participants can provide insights into cultural issues that are important for effectively communicating and discussing water and sanitation problems. Typically, these discussions are conducted over a period of one to two hours.

In particular, focus group discussions will help in identifying (or confirming) the major constraints to connecting to network services, such as unaffordable connection charges, or inaccessible credit facilities. In that case, split sample tests should take into account the effects of the connection charges on WTP values. If the primary complaint about

²³ Note that some focus group discussions should be conducted at the initial preparatory stage to understand the WSS situation. However, the focus group participants should be carefully selected after sampling communities or areas have been identified using the sampling framework, so that this group of participants will not be included in the main survey sample.

the existing service is its reliability (e.g., hours of supply), this item should be considered as a key attribute of the improved services, and should be included in designing the questionnaire. Thus, the focus group discussion helps the analyst revise the design features of the preliminary survey instrument. The focus groups are also likely to identify additional issues that are difficult to specify at this point but may need further examination during pre-testing. For example, the analyst may gain insights on data quality issues such as the precision with which to measure volumetric water consumption and consumption expenditures. Therefore, researchers should use the focus group discussion to refine the CV scenario and the questionnaire depending on the issues at hand.

4.5.4 Pre-testing and Finalizing the Questionnaire

Pre-testing is a small-scale implementation of the draft questionnaire (normally for about 20–50 questionnaires, depending on the number of different versions of CV scenarios designed). Its primary purpose is to identify any problems with the content, length, and flow of the questionnaire. After refining the survey questionnaire based on comments from stakeholders, focus group findings, and enumerator training, the instrument is ready for pre-testing with respondents drawn from the target population.²⁴ A verbal debriefing of the pre-test participants is crucial to address the following issues related to the CV questions:

- (i) understanding of the water and sanitation services that are offered (i.e., effectiveness in conveying the change in WSS attributes and the contingent nature of the product that respondents agree to purchase)
- (ii) recognition of how the proposed service is different from current service options (including no service)
- (iii) consideration of income constraints and alternative uses of income
- (iv) appropriateness of the payment vehicle
- (v) appropriateness of the range of bids
- (vi) identification of any culturally sensitive element or question in the survey instrument.

²⁴ Again, the participants for the pre-testing stage should be carefully selected, so that this group of participants will not contaminate the random sampling process and survey data afterwards.

The pre-tests provide several benefits in addition to giving enumerators further training. Firstly, they help determine the appropriateness of the commodity definition. Second, the analyst can use the pre-tests to gauge the appropriateness of the bid distribution, the highest monthly consumption charge (i.e., a price that will be rejected by 90–95% of respondents), and the lowest charge (i.e., a price that will be accepted by 90–95% of the respondents). This ensures that the range of bids is appropriate so the survey will provide credible results. Third, participants' responses to open-ended questions identified in the focus groups can be pre-coded in the survey instrument to facilitate data entry and subsequent analysis. Lastly, the researcher can observe the way enumerators conduct the survey to identify common mistakes. These mistakes should be discussed at the group meeting of the survey team. Videotaping the pre-test interviews help other enumerators understand some of the common mistakes made by fellow enumerators. A simple enumerator manual, with specific instructions regarding common mistakes and errors, can be prepared based on the overall findings. Furthermore, field coordinators should be instructed to check these common mistakes on a survey-by-survey basis to identify problems early in the implementation process.

The pre-tests help finalize survey logistics such as formation of groups, assignment of field supervisors, and transportation of enumerators. Thus, the pre-tests will finally validate the questionnaire and provide adequate confidence to the researcher that the questionnaire is appropriate and ready to be used.

4.5.5 Supervising Survey Implementation

The goal of this sub-task is to properly administer the survey to the predetermined sample. Enumerators and field coordinators will be divided into teams. The number of teams and the size of each team will be determined by the sample size. In general, one field coordinator can supervise 4 to 5 enumerators. The survey should be completed all at once, taking no longer than 2 or 3 weeks to complete. Several quality control and quality assurance activities, summarized by Scott et al. (2005) for example, are key elements of field supervision.

While field coordinators will be responsible for day-to-day operations, the core study team should constantly monitor survey progress on a daily basis from the beginning to the later phases of the field work. As interviewers and field coordinators gain experience with the survey, supervision and monitoring activities can be reduced, although not ended until the conclusion of the survey. A systematic supervision of the field survey involves: (i) ensuring that the intended sample is interviewed, (ii) a detailed review of every completed questionnaire before leaving the location, (iii) assessing the quality of interviews, (iv) random checking of interviews, and (v) implementation of an incentive scheme to improve the performance of enumerators.

At the end of each field day, coordinators should check the returned questionnaires for completeness and accuracy, according to a quality checklist developed by the study team. If any discrepancies are detected, the enumerators should return to the households to correct the errors or fill in the missing information. Recording enumerators' opinions regarding the quality of the interviews will also be useful. A log of returned surveys will provide a quick overview of the progress of survey administration. The core study team and coordinators should also periodically monitor interviews for quality assurance. Collectively, these measures can ensure that mistakes made by enumerators are spotted and corrected at an early stage, thereby setting a standard for quality control and quality assurance as the survey progresses. Strengthening enumerator training, focus group discussions, pre-testing, and supervision of field work ensure improved data on WTP for WSS through CV studies.

4.6 Data Management and Preliminary Analysis

While the survey is progressing in the field, the analyst should also begin developing a coding sheet and template for data entry. Once good quality data is generated through the survey, the analyst should make sure errors will not appear at the data entry and management stages. The management and analysis of data from the survey often proceeds in three sets of sub-tasks corresponding to: (i) data entry and processing, (ii) calculation of descriptive statistics, and (iii) cross-tabulation of summary statistics.

4.6.1 Data Entry and Processing

The data recorded on the questionnaires should be transferred by the analyst into the selected data management software (e.g., Microsoft Excel, Access, Fox, or CSPro developed by the United States Census Bureau, Macro International, and Serpro, S.A.) using codes developed during the survey design. Three quality assurance and quality control procedures can be employed: range check, intra-record check, and final consistency check (Munoz 2003). Range and intra-record checks should be undertaken during data entry. By building a proper data entry template, the operator is only allowed to proceed to the next question if the data for the current question falls within the allowable range of responses for each question. An intra-record consistency check can be administered immediately after entry of each questionnaire. For example, family size reported by the household head should equal the number of family members listed in the family roster.

A final scan for overall consistency should be conducted when all questionnaires have been entered. This final consistency check will ensure that values from one question are consistent with values from another question. In addition, it is helpful to conduct spot checks on the data entry operation, to double-enter 10% of the full survey, and to double-enter 100% of critical modules such as the WTP elicitation response, in order to ensure that there are no discrepancies between the hard copies and the electronic data set.²⁵

4.6.2 Descriptive Statistics

The household and community surveys combined with supplementary administrative data can add up to a large data set. While some variables are of independent interest, others must be combined to produce policy relevant statistics. In general, such data should be described at two levels. The analyst should compute descriptive statistics (e.g., mean, median, standard deviations, and range) to understand and describe all of the variables in the data set. Examining the descriptive

²⁵ “Double-enter” means that a different person would enter the data from the selected questionnaires (or modules) onto a separate Excel sheet. The two Excel sheets (original and double-entered) would be compared electronically to determine whether the original sheet accurately records the responses from the questionnaires.

statistics will serve as an additional quality assurance and quality control measure because the analyst will be able to identify anomalies, outliers, and improbable values. If outliers are found, the analyst should check against the questionnaires by matching respondent identification numbers. If necessary, the enumerator who administered that particular questionnaire should be sent again to clarify and to confirm with the respondent.

It can be useful to identify subpopulations of policy interest for further estimation of descriptive statistics. Typically, these are identified by: (i) WSS user type (e.g., private water connection or public tap); (ii) socioeconomic group (households in different consumption quintiles); and (iii) physical subregions of the study area (e.g., administrative units). In most cases, the analyst may be particularly interested in the subpopulation of households living in poverty, for which the definition of poverty is critical. Data on household consumption expenditure can be validated against income, wealth and assets, caloric intakes, demographics, and housing quality to generate a statistically robust and economically meaningful poverty indicator. The set of variables one has to use in characterizing households will also vary with the study site and specific objectives of a study.

4.6.3 Cross-tabulation of Summary Statistics

Cross-tabulations by socioeconomic, geographic, and current use status should be calculated for all important variables including demand for WSS improvements, water quality perceptions, and consumption. This process will provide descriptive statistics on subpopulations of interest such as the poor, the unconnected, and the marginalized zones of the study area. The descriptive statistics will provide a profile of the socioeconomic characteristics of the typical households as well as a typical household belonging to a subgroup, such as poor unconnected households. These cross-tabulations offer preliminary evidence on underlying relationships between socioeconomic conditions and types of service needs (Deaton 1997).

The story presented by the descriptive statistics should tally with the initial informal characterization of the existing WSS service. Percentage distributions of income and water sources should show similar patterns

of distribution with the study population. Cross-tabulations of key selected variables should generally indicate (positive or negative) correlations based on expectations (e.g., the higher the income level, the higher the number of assets owned). A serious disconnect between the initial understanding and the description provided by the data indicates some errors, perhaps during the data entry process. If cross-tabulation of WTP values with key variables (expected to be correlated with WTP values) is generally consistent with hypothesized patterns, and tallies to a reasonable extent with initial characterization, the analyst can move to the next step: estimation of WTP and policy simulations.

4.7 Using CV Study Results

Once data quality is assured through the examination of descriptive statistics, the analyst then proceeds to: (i) undertake validity tests and estimate mean WTP using econometric models; (ii) assess the effective demand for WSS; and (iii) carry out policy simulation as required by the specific context of the CV study.

4.7.1 Validity Tests and Estimating Mean WTP

To establish the accuracy of CV studies, the analyst may evaluate the survey responses by examining three characteristics: validity, reliability, and precision. Validity refers to whether survey respondents have answered the question the interviewer attempted to ask. Reliability refers to the size and direction of bias that may be present in the answers. Precision refers to the variability in responses.

Validity can be of two types: convergent validity and construct validity. Convergent validity²⁶ generally refers to the temporal stability of WTP estimates. It can be assessed by examining the consistency of WTP estimates over time through repeated surveys of the same individuals. Other methods of assessing convergent validity include: (i) comparing WTP estimates with similar values derived from revealed preference data; (ii) comparing WTP estimates with respondents' actual behavior

²⁶

Convergent validity can also be assessed when different estimates of WTP are obtained using different methods for the same sample at the same time.

when they participate in experiments that simulate the market for the commodity in question; (iii) calibrating the respondents' valuation of goods in various ways to get more accurate WTP estimates; and (iv) comparing the WTP results obtained using different elicitation methods. From a practical point of view, examining convergent validity is not practically feasible during a project preparatory CV study.

Construct validity refers to how well the measurement is predicted by factors that one would expect to be predictive a-priori. Here the analyst can examine the consistency of CV results with the predictions of economic theory. In a study of this nature, construct validity can be readily checked by estimating a regression model, essentially a WTP function²⁷ that relates a respondent's WTP to the individual's characteristics and to the characteristics of the commodity. Multivariate regression can be used to examine the validity of WTP data by testing hypotheses based on the statistical significance of the estimated regression coefficients.

As the first step in developing a regression model, the analyst should select a set of independent variables to specify the model. There are many relevant empirical studies analyzing WTP values through multivariate regression models. Depending on the elicitation technique, the selection of regression models has been extensively studied. In particular, if yes/no binary data are collected through the referendum vote technique, probit or logit models need to be used to estimate WTP. Associated independent variables to explain WTP are reported in many papers, such as Altaf et al. (1993), Cameron (1988), Haneman (1984), Mu et al. (1990), Choe et al. (1996), Gunatilake et al. (2006), Lauria et al. (1999), and Whittington et al. (2002). However, construction of the regression model (and thus selection of independent variables) should be based on economic theory and on the analyst's hypothesis on the relationship between WTP and household socioeconomic characteristics, water consumption patterns, and preferences. The appropriate variables need to be determined at an early stage to ensure that they are included in the survey instrument. The following are some of the potential variables that can serve as independent variables, though the list is not exhaustive:

- (i) bids (monthly bills)
- (ii) design features in the CV scenario such as a one-time connection fee for those who are not currently connected,

²⁷ The type of econometric model used in developing the WTP function varies with the type of elicitation question. For example, the open-ended format estimates the WTP function with tobit models, while dichotomous choice models use probit or logit models.

service provision by the public or private sector, dummy variables for the poor and non-poor and for geographic areas.

- (iii) water source characteristics such as number of water sources accessed and used, the price of water from the traditional water source, time of the household required in accessing the traditional water source, and the household perception of the quality of water from the traditional water source
- (iv) household characteristics such as household income or wealth, education of household members, health history of household members, occupation of household head, family size, ethnicity, religion, sex of respondent, and age of respondent
- (v) any other location-specific variable that could potentially have an impact on WTP for the WSS.

Once the multivariate regression is estimated incorporating the above set of variables, the analyst can undertake the validity tests. If the explanatory variables show a statistical significance in the hypothesized relationship with the dependent variable, then the WTP values from the CV survey can be considered valid. More specifically, the following relationships are hypothesized generally, and checked to test the validity of responses to the elicitation question:

- (i) a positive and significant coefficient for income
- (ii) a negative and significant coefficient for the bid and connection charges
- (iii) a positive and significant coefficient for monthly per capita consumption
- (iv) a positive and significant coefficient for coping costs, education level, and incidence of water-related disease
- (v) a negative and significant coefficient for availability of substitute sources such as wells.

In addition to the above commonly used variables, depending on the context of the project the analyst can use a number of other variables to test the validity of the WTP estimates. If these tests—particularly the price- and income-related tests—provide expected results with the required statistical significance, this shows that the respondents have understood the CV scenarios, and that they have answered the questions

accurately. Once the validity tests show that the CV data are accurate, the analyst can proceed to estimate mean WTP. Mean WTP can be estimated for the entire sample as well as for subsamples of policy interest. Mean WTP values of respondents can be estimated using econometric models (Hanemann 1984, Cameron and James 1987, Cameron 1988). Box 4.1 illustrates the approach to estimate mean WTP using a probit regression model. The theory is set out in Appendix 4.5.

Besides conducting validity tests and estimating WTP, multivariate regression results can be used to predict the rate of acceptance (uptake rate) of the improved services under different policy scenarios; and to generate a function that can be used for other projects.²⁸ These types of analyses can help answer some of the policy questions arising in designing tariffs and subsidies for WSS projects.

4.7.2 Demand and Policy Analysis

Given a good CV study, establishing the effective demand for improved services is relatively easy. A properly designed and administered CV study is a good source of information for demand analysis of proposed WSS services. The results of a CV study, together with the estimated WTP functions, can be used to gauge effective demand and to predict the rate of acceptance of a proposed improvement in water supply. In order to understand the impact of income on effective demand, the estimated WTP function can be simulated as shown in Chapter 4. Simulation can be done using different income levels. Sometimes, a proxy for income is incorporated in the regression models when accurate income data are difficult to obtain. An index of assets the household currently possesses and the household monthly expenditure, for example, can be used as proxies. When reasonable data about future income or any change in related variables are available, these data can be used to predict future demand for improved services.

To predict acceptance of the improved services among respondents, household characteristics of the subpopulation of interest and attributes of a WSS service (reliability, charges, quality) can be used in the simulation exercise. This prediction exercise could be repeated for alternative scenarios to generate a series of probability maps of coverage under

²⁸ Through the benefit function transfer method, as discussed in Chapter 6.

Box 4.1 Estimating Mean WTP: An Illustration

The approach involves estimating a probit regression model where the dependent variable is a yes or no answer as to whether the respondent is willing to pay the specified bid price for the water service on offer. The probit model will be of the form

$$Y = \alpha + \beta_1 X + \beta_2 B + \epsilon$$

where Y is the yes/no response, X is a vector of variables reflecting household, area or other characteristics, B is the bid price and ϵ is an error term. Mean WTP is derived from the expression

$$(\sum(\beta_1 * X^a) / \beta_2)^{-1}$$

where X^a is the mean value of X variables.

Mean WTP is thus derived by first summing the product of the regression coefficients for the variables and their mean from the probit analysis ($\sum(\beta_1 * X^a)$) and then dividing this by the coefficient on the bid price (β_2). This expression is then multiplied by minus unity to give a positive number. Where, as illustrated above, there is a constant in the probit model (α) this must be added to the sum of the products to give $(\alpha + \sum(\beta_1 * X^a))$ so that mean WTP becomes

$$(\alpha + \sum(\beta_1 * X^a) / \beta_2)^{-1}$$

This approach is illustrated below using realistic data from a CV study on improved water provision. Monetary units are Renminbi (RMB).

Mean Willingness to Pay Calculation			
Variable	Coefficient	Mean	Coefficient*Mean
Bid	-0.19779		
Income	0.00002	24,501.0	0.48468
Education	-0.00826	10.60700	-0.08765
Gender	0.04213	0.49380	0.02080
Age	-0.01020	43.27100	-0.44149
Dwelling	0.11087	0.58058	0.06437
Yard	0.00146	121.68000	0.17805
Impact	-0.07108	4.38220	-0.31146
Squality	-0.12587	3.04340	-0.38307
Constant	1.89640		1.89640
Total			1.42062
Mean WTP	=1.42062 / -0.19779 * -1		7.18249

The same approach can be applied to derive mean WTP for specific target groups by replacing the average value for each variable X (for example, RMB 24,501 for income) with the specific X value for the group concerned (for example, RMB 20,000 for the very poor).

service alternatives (Pattanayak et al. 2006). Such simulations will help the analyst predict the service coverage and output of the WSS plant with reasonable accuracy under the most probable future scenarios. This information can then be fed back to engineering designs to avoid under-capacity or excess capacity issues in designing water supply plants. The predicted uptake rates with the most plausible policy scenario answer the effective demand question directly and provide additional information on financial sustainability, and overall viability of the WSS project.

The estimated WTP values have a number of important uses such as calculating the benefits of the proposed improvements to the water supply system, setting tariffs, and making informed decisions on related policy issues. Calculating project benefits using WTP estimates is straightforward. Once the analyst gets reasonable confidence about the estimated mean WTP value, it can be readily used in project economic analysis. The mean WTP multiplied by the number of households served by the project provides the total gross benefit of the project.

The use of WTP estimates in setting tariffs is also reasonably straightforward, but some understanding is required to avoid its misinterpretation and misuse. CV surveys provide measures of the maximum WTP for proposed improvements in WSS in the context of the existing or proposed institutional regime. The WTP is related but not equal to the future demand or monthly bill paid by the households to the water utility. Although future demand and WTP contain similar behavioral information on household preferences, WTP is different because it is an *ex ante* measure of welfare change associated with the improved WSS. It will not show how much water will be consumed when services are improved, or how many households will be connected to the improved service with a revised tariff and connection charges. Therefore, WTP cannot be used to estimate revenue directly, because households will pay only a proportion of the maximum WTP expressed in the CV study. Moreover, basic economic principles suggest that monthly charges should be equal to or less than mean WTP. Therefore, a tariff that charges above mean WTP will lead to welfare losses and is likely to discourage households from connecting to the water services. Therefore the WTP²⁹ should be treated as the upper bound of the tariff. Furthermore, tariff setting requires additional information because it requires meeting a set of goals combining financial sustainability, economic efficiency, and

²⁹ The bids and number of "yes" answers can be used to predict the revenue although the mean WTP is not an indicator of revenue.

distributional equity (Dole 2003, Dole and Bartlett 2004, Dole and Balucan 2006). In addition to WTP therefore, information on the cost of delivery, capital replacement requirements, and various social considerations should be used in setting tariffs.

Finally, the estimated WTP functions can be used to analyze policy issues related to designing WSS projects such as the choice of provider, the design of spatially based pro-poor service delivery, the affordability of the poor, and the characterization of low WTP groups.

4.8 Concluding Remarks

CV studies are widely used in designing WSS projects. The application of the CV method in developing countries is a cause for concern because poorly designed and administered CV studies produce unreliable WTP estimates. Unreliable CV results are largely due to poor study design, poor survey implementation, and failure to undertake a variety of tests to examine the validity of responses to the different CV scenarios. The CV method has undergone significant improvements during the last 20 years. Advances in econometric analysis, survey research methods, sampling and experimental design, and policy simulations in the last two decades have been remarkable.

This chapter aims to motivate practitioners to use these improved methods to obtain reliable WTP estimates. It recommends a number of good practices that can be applied in the design, survey implementation, and data management and analysis stages of a CV study. Table 4.2 provides a checklist that a CV study team can use in examining whether a CV study has applied best practice methodology to estimate WTP. If answers to the questions in the table are satisfactory, it is expected that the resulting study will be useful for policy purposes. The next chapter provides an example of the application of the good practices described in this chapter.

Table 4.2 Quality Checklist

Attributes/Procedures		Relevant Questions	
1.	Design Issues		
1.1	Pre-characterization of WSS	1.1	Has the study team undertaken adequate pre-characterization activities?
1.2	CV Scenario	1.2	Does the study use a realistic CV scenario?
1.3	Commodity Definition	1.3	Does the commodity definition provide a complete and precise account of improved WSS?
1.4	Elicitation Method	1.4	Does the study use referendum elicitation format?
1.5	Bid Distribution	1.5	Does the study use reasonable bids with adequate range to understand the demand?
1.6	Sample	1.6a	Is the sample size adequate?
		1.6b	Is the sampling frame and method reasonable?
		1.6c	Has the study team strictly implemented the sampling strategy?
		1.6d	Was there a replacement method?
2.	Survey Instrument		
2.1	Focus Group Discussions	2.1	Has the team undertaken enough focus group discussions and have they been used to refine the instrument?
2.2	Pre-testing	2.2	Has the team undertaken enough pre-tests and have the findings been used to refine the instrument?
2.3	Quality of Survey Instrument	2.3	Is the overall quality of survey instrument satisfactory?
3.	Potential Biases	3	Has the team considered bias minimizing measures in designing and conducting the study?
4.	Survey Implementation		
4.1	Enumerator Training	4.1	Have the enumerators been given adequate training emphasizing the accuracy of the data and minimizing biases?
4.2	Field Supervision	4.2	Has there been adequate effort to ensure quality of data through supervision of field work?
5.	Data Management		
5.1	Quality Checks	5.1	Have adequate quality checks been incorporated while entering data?
5.2	Preliminary Analysis	5.2	Do the descriptive statistics tally with secondary administrative data?

continued on next page.

Table 4.2 continued.

Table 4.2 Quality Checklist		
Attributes/Procedures		Relevant Questions
6.	Validity Tests	6 Has a validity test been undertaken? Do results confirm positive income elasticity, negative price elasticity, and other theoretical expectations?
7.	Estimation of Mean WTP	7 Has appropriate econometric modeling been undertaken to estimate mean WTP? Does the estimated value fall within similar previous estimates?
8.	Demand Analysis	8 Does the analysis demonstrate that there is effective demand for proposed improved WSS services?
9.	Reporting	9 Does the CV study report contain adequate information to answer the above questions?

CV = contingent valuation, WSS = water supply and sanitation, WTP = willingness to pay.
Source: Gunatilake, et al. (2007).

APPENDIX 4.1

Determining Minimum Number of Sample Size Based on Population Size

Population size	Sample size	
	Continuous data (margin of error=.03)	Categorical data (margin of error=.05)
	$\alpha = .05, t=1.96$	$\alpha = .05, t=1.96$
1,000	106	278
1,500	110	306
2,000	112	323
4,000	119	351
6,000	119	362
8,000	119	367
10,000	119	370

α = significance level; t = critical t value corresponding to 0.05 level of significance.

Note: The table shows the minimum sample size to ensure good statistical properties given the size of the population and acceptable margin of errors. In a contingent valuation study, we use many categorical data variables and the probit model itself uses a categorical data variable as the dependent variable. As explained in the main text, a bigger sample size may be needed when split sample tests, range of bids, and various other design features demand large size subsamples.

Source: Bartlett et al. (2001).

APPENDIX 4.2

Strengths and Weaknesses of Different CV Elicitation Methods

Elicitation Method	Major Strengths	Major Specific Weaknesses	Generic Weaknesses
Open-ended WTP method	No starting point bias. May directly measure exactly what researcher wants to know. A good check when used in conjunction with other methods.	High information complexity leads to unrealistic responses in hypothetical situation.	
Closed-ended iterative bidding method	Bidding provides “thinking time” to elicit maximum WTP, as desired.	Sensitive to starting value. “Bidding frenzy” may lead to some very high valuations.	Apply to most survey methods:
Contingent ranking method	Ordinal ranking requires low information complexity. Links quantities to prices, reducing hypothetically.	Ordinal responses cannot be aggregated. Requires analyst to have statistical skills. Anchoring bias and highly dependent on the specified alternatives. Requires fairly large sample sizes.	sample selection bias; non-response bias; outliers; unintended interviewer biases.
Dichotomous choice method	“Take it or leave it” choices reduce hypotheticality and approximate the market. Small strategic bias; very small starting point bias.	Less information per respondent, so large samples are needed. Requires analyst to have statistical skills.	Apply especially to CV methods: hypotheticality bias; payment vehicle; non-commitment bias; order bias; embedding bias; strategic bias.
Payment card with comparative tax-prices	Encourages realistic assessment of WTP, thus reducing hypotheticality and non-commitment bias.	Moderate to high information complexity. May be too sensitive to particular comparisons. Anchoring bias. Often requires personal interviews.	
Payment card with a range of prices for the good	Moderately low complexity. Low interview bias.	Anchoring bias. Often requires personal interviews.	

CV = contingent valuation, WTP = willingness to pay.
Source: Boardman et al. (1996).

APPENDIX 4.3

Measures to Reduce Bias

In general, CV surveys are subject to various biases, like any other surveys. Much of the early experimental literature focused on testing for and identifying biases such as item non-response, non-neutrality, compliance bias, non-commitment bias, and starting point bias (Smith 2006). Over the course of the last 25 years of methodology development, these are not deemed to be unique to CV surveys per se. As Griffin et al. (1995) contend, the CV method may be particularly prone to hypothetical bias, strategic bias, and compliance bias. These biases can be addressed throughout the preparatory tasks, sample selection, survey question design, enumerator training, and econometric analysis discussed in this chapter.

The table below provides a summary of the biases and potential measures to reduce them. See Gunatilake et al. (2006) for more discussion on the biases. Analysts should use the information with caution because the risks of biases can vary from one study site to another, and they are only indicative. Minimizing biases should be at the back of the mind of the analyst throughout the design, implementation, and analysis of the CV study. However, the table may be referred to as a checklist to guide the analyst before launching the fieldwork and to ensure that necessary steps have been taken to minimize biases.

Potential Biases in WSS CV Studies and Measures to Minimize Them		
Bias	Risks in WSS Studies	Measures for Minimizing Bias
Sampling bias Sample may exclude a particular subgroup from the population	Medium	Strict implementation of sampling strategy, proper replacement strategy, large sample, split sample analysis. If there is a systematic pattern of non-response, some analysis on the excluded sub-category may be required.
Non-neutrality Researchers influence the choice. Respondents attempt to please.	High	Enumerator training on neutrality, questionnaire pre-testing, focus group discussions, and supervision during survey implementation. See Whittington (1998, 2002b) on training urban enumerators who may look down and/or coach their respondents, who are already inclined to give an answer that pleases the enumerator.

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Table continued.

Potential Biases in WSS CV Studies and Measures to Minimize Them		
Bias	Risks in WSS	
	Studies	Measures for Minimizing Bias
Hypothetical Respondents provide hypothetical answer to value a commodity offered in the future	High	Formative research (focus groups, key informant) discussion to understand the context and the commodity. Proper CV scenario design, appropriate and credible payment vehicle, debriefing questions, CV scenario with minimum uncertainty of the provision of the commodity.
Starting point Respondents anchor to the initial values given to them.	High	Proper elicitation question, proper bids with adequate range. Closed-ended questions may have very small starting point bias. Iterative bidding method is especially prone to this bias.
Strategic behavior Respondent purposely eliciting choices with the objective of future free-riding	Medium	Proper elicitation question, proper debriefing questions, removal of the questionnaire if there is clear evidence of strategic answers. Closed-ended format reduces the strategic bias. Enumerator training to pay attention to strategic bias during the interviews.
Non-response Respondent refuses to answer the question	Medium to high	Preparatory work on phrasing and content should reduce non-response. Refusal should be probed with follow-up questions to gauge "protest" intentions. Informed consent is necessary before starting surveys. Well mannered and neutral enumerators can minimize this risk.
Embedding effect WTP does not vary with the quantity of the good	Low	May not be serious in WSS CV studies. Common in valuation of public goods such as biodiversity in which quantification is difficult. Quantity (or service quality) can be incorporated to check whether WTP is sensitive to the quantity consumed. Conjoint analysis can also help in identifying this bias.

CV = contingent valuation, WSS = water supply and sanitation, WTP = willingness to pay.
Source: Gunatilake, et al. (2007).

APPENDIX 4.4

Rules of Good Interview Practice: Do's and Don'ts For Enumerators

No.	Advice	Comment
1	Read every question exactly as written in the questionnaire – Do not improvise	Research on the art of asking questions shows that the precise wording of questions may significantly affect a respondent's answers. If each enumerator develops her own way of asking questions, one can never be sure that the same question is being asked. We need to make sure that each respondent is answering the same question. Reading the question exactly also makes the interview shorter.
2	Read the question slowly enough so that the respondent can understand.	An enumerator has seen each question hundreds of times before. It's natural for the enumerator to want to go quickly over a question that he knows so well, but it's the first time for the respondent. The enumerator thus needs to speak slowly.
3	Wait for the respondent to answer	Some enumerators will read the question once, then look up and repeat the question, and sometimes even start a lengthy explanation, before letting the respondent answer! Ask once very clearly, and let the respondent think.
4	If the respondent can't answer, repeat the question.	The respondent may not have been paying attention the first time. If, after the second reading the respondent still can't answer, go to the next question.
5	Remain absolutely neutral about the respondent's answers	Never express surprise, approval, disapproval, judgment, or doubt about a response. Don't let your facial expression change. Just record the answer. For example, if a respondent says that they would be willing to pay a very large amount for a good or service, the enumerator should not say, "wow!" If a respondent gives an answer that is factually wrong, the enumerator should not reveal that he knows the answer is incorrect.
6	Do not act embarrassed about a respondent's answers to sensitive questions.	This will increase the embarrassment of the respondent, not reduce it. Be very matter of fact.

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Table continued.

No.	Advice	Comment
7	Never suggest an answer unless the instructions say to read the answers to the respondent.	For example, if the respondent is having difficulty estimating the most he will pay for a good or service, do not prompt him with suggestions like... "would you pay more than US\$xx? Less than zz?"
8	Don't repeat the respondent's answers.	This is repetitive and wastes time.
9	Conduct the interview in private.	That means that the interview should not be in earshot of other people in the household. If someone doesn't want to leave, the enumerator should offer to interview him or her separately. If they still won't leave, then the enumerator should explain to the respondent that he will have to return later.
10	Do not give advice to respondents on personal matters.	Enumerators should refer respondents to the appropriate authorities for answers to questions that may arise that are outside the scope of the interview.
11	Answer directly any questions the respondent may have about the purpose of the survey	Respondents are entitled to know the purpose of the survey and how they have been selected to be interviewed. The enumerator should not be reluctant to take time to provide clear, detailed answers to such questions.
12	Listen carefully to the respondent's answer	It is very off putting to the respondent if the enumerator is inattentive. Moreover, the respondent may be offering an answer that is in fact different than it first appears to be. In such cases the enumerator needs to be listening carefully to hear what is actually being said.

Source: Whittington (2002b). Original sources cited are: (1) Martha Ainsworth, The World Bank. Personal communication; and (2) Amon, J., T. Brown, J. Hogle, J. MacNeil, R. Magnani, S. Mills, E. Pisanti, T. Reble, T. Saidel, and C. K. Sow.. 2000. *Behavioral Surveillance Surveys (BBS): Guidelines for Repeated Behavioral Surveys in Populations at Risk of HIV*. Family Health International URL: www.fhi.org. Funded by USAID and the United Kingdom DFID.

APPENDIX 4.5

Estimation of Mean Willingness to Pay (WTP) from Closed-Ended Contingent Valuation Data

This appendix explains the theory and procedure for estimating mean WTP using the data generated through dichotomous choice (closed-ended) elicitation method. The theory behind the estimation of mean WTP is explained first.

Assume that the household's utility depends on a composite commodity X^{30} and left over money (Y) available for paying a water bill. Utility has a deterministic component (first and second terms of the right hand side of equation [1]) and a stochastic component, ε . Utility of the household before answering the contingent valuation (CV) question is:

$$u_o = X_o\beta + \gamma Y + \varepsilon_o \quad (1)$$

Utility of the household can be given by equation (2) if the household answered³¹ "yes" to the CV question, where WTP is the maximum amount of money the household is willing to give up to obtain the improved WSS services.

$$u_1 = X_1\beta + \gamma (Y - \text{WTP}) + \varepsilon_1 \quad (2)$$

By subtracting (2) from (1) we get

$$u_o - u_1 = (X_o - X_1)\beta + \gamma \text{WTP} + \varepsilon_o - \varepsilon_1 \quad (3)$$

By replacing $(X_o - X_1)$ with X , we get³²

$$u_o - u_1 = X\beta + \gamma \text{WTP} + \varepsilon_o - \varepsilon_1 \quad (4)$$

Taking the expected value (E) of both sides of equation (4) we get

$$E[u_o - u_1] = E[X] * E[\beta] + E[\gamma] * E[\text{WTP}] + E[\varepsilon_o - \varepsilon_1] \quad (5)$$

Further simplification will result in:

$$E[u_o - u_1] = E[X] * \beta + \gamma * E[\text{WTP}] + E[\varepsilon_o - \varepsilon_1] \quad (6)$$

In answering the CV question, the respondent maintains the same level of utility by giving up an amount of money equal to WTP and

³⁰ X should be viewed as a vector of commodities and β as a vector of corresponding regression coefficients.

³¹ Here we assume that the household actually behaves according to the answer.

³² X will account for the difference in the consumption of the composite commodity due to the decision to purchase improved water services

acquires the improved service. By doing this, the household maintains its original utility level, therefore, u_0 and u_1 are equal. Thus:

$$0 = E[X] * \beta + \gamma * E[WTP] \quad (7)$$

$$E[WTP] = - (E[X] * \beta) / (\gamma) \quad (8)$$

Equation (8) can be used to estimate mean WTP for the study sample.

In a closed-ended CV study, households are provided with a set of bids (bids are randomly assigned among the survey participants) and asked whether the household is willing to pay the given bid amount for the improved water supply and sanitation, in the form of increased water bills. Answers to this question come in the form of “yes” or “no”. The dependent variable for the econometric model is formed by assigning 1 for “yes” and 0 for “no” answers. Then a probit regression model is estimated incorporating a set of relevant independent variables and the bid. Equation (8) is used to calculate the mean WTP. First, regression coefficients in the estimated probit model should be multiplied by the mean values of the corresponding X variable and these products are summed up.³³ After summing them, the resultant value should be divided by the coefficient of the bid variable. Finally, this result should be multiplied by -1 to obtain mean WTP. The same procedure can be used to calculate WTP for each household. Instead of the mean values of X variables, actual values for the household should be used to get the overall intercept in calculating the WTP for a household.

³³ If the regression equation includes an intercept (or constant), that also should be added to this sum.

5. Assessing the Willingness to Pay (WTP) for Improved Water Supply in Sri Lanka

5.1 Introduction

Water supply and sanitation (WSS) services have traditionally been provided by the public sector, meaning the provision of such public sector goods and services is generally decided through political processes rather than in response to market signals. This often results in a decoupling of burdens from benefits—that is, because users do not pay directly for such public services, taxpayers bear the cost of provision, yet beneficiaries may not share in the cost because not everyone in poor countries pays taxes. At the same time, such single-source production, as a form of natural monopoly, frequently prevents competition. The lack of an exit mechanism, as one sees in market-driven economic activities, sustains the delivery of WSS despite an often poor performance. These characteristics together, make WSS projects prone to huge inefficiencies. Hence, investigating the effective demand for WSS services and accurately estimating the benefits are of paramount importance before launching a WSS project.

In 2002, the Government of Sri Lanka investigated the feasibility of private sector participation in the provision of WSS in two service areas of the country's southwestern coastal belt: Negombo and the coastal strip from Kalutara to Galle. Its intention was to attract local private investors, preferably in a consortium with international water companies, to establish a public-private partnership (PPP). The proposed contracts were to last for 15 years and the operators would be remunerated, as specified in the contracts, through a fixed tariff for every cubic meter of water delivered and sold to the consumer.

According to the initial design, the operator would collect revenue from the consumers on behalf of the government, retain its fee, and remit the difference to the government. The government, in turn, would reinvest these funds in the water supply system. The proposed PPP had planned to charge different connection fees in the two service areas. In Negombo, connection charges were to be subsidized, while in the coastal strip from Kalutara to Galle, consumers were to pay the full cost of connection. The proposed contract had the following features:

- (i) **Universal service obligation.** The government's objective was to extend piped water service in the two service areas to 95% of the population. Given pre-existing coverage of just 38% of households in the study area, this was considered ambitious.
- (ii) **Service performance specification.** Service levels were to meet certain standards, including 24-hour supply and water quality.
- (iii) **Tariff and subsidy policy.** Investment needs were large if a 95% coverage target was to be met. Tariffs would need to be increased significantly, up to 100% of the pre-existing tariff, for operators to realize a reasonable return on investment. The government planned to raise tariffs gradually and provide subsidies until the tariff was adequate.
- (iv) **Tariff structure.** The government wanted to maintain the pre-existing tariff structure (increasing block tariffs) on the premise that this would benefit the poor.

This chapter illustrates how good practices, as discussed in Chapter 4, were employed in conducting a contingent valuation (CV) study for assessing demand for improved water services and designing tariffs in Sri Lanka. It also shows how the results of the study were used to facilitate the design of a PPP to provide WSS services. Section 5.2 briefly discusses the preparatory work undertaken for the study. Section 5.3 examines study design issues, focusing on the measures taken to reduce potential biases. Section 5.4 explains how the CV study was administered and implemented. Section 5.5 presents the findings of the CV study and Section 5.6 discusses the results of conjoint analysis. The final section provides concluding remarks.

5.2 Initial Preparatory Tasks

The CV study was undertaken by a team of experts from the United States' Research Triangle Institute (RTI) International, in collaboration with Sri Lanka's University of Peradeniya, with financial support from the World Bank–Netherlands Water Partnership. In preparation, the team gathered and reviewed basic sector information, conducted a series of focus group discussions (FGDs), and held several discussions with households and relevant government agencies, principally the National Water Supply and Drainage Board (NWSDB) and the Water Resource Secretariat.

Prior characterization of the existing WSS in the study area was based on a review of existing literature covering previous WSS and poverty studies, field observations, unstructured open-ended interviews, participatory community meetings, and small FGDs. The initial preparatory work also provided a comprehensive overview of the local conditions at the study sites including: (i) primary water supply options, (ii) existing and potential levels of water supply services, (iii) current charges and costs, (iv) the role of sanitation and hygiene in prevention and control of waterborne diseases, and (v) a basic socioeconomic profile of the respondent population.

In addition, the team used handheld global positioning system (GPS) units to map households and community infrastructure in the area. These maps were used to assess differences in WSS demand between poor and non-poor households, identified according to monthly consumption expenditure. The overlay of household and infrastructure maps allowed the team to investigate spatial patterns and the potential for zonal subsidies and geographic targeting.

5.3 Study Design Issues

5.3.1 Sampling Strategy

As discussed in Chapter 4, designing the sampling strategy involves: (i) defining the population, (ii) identifying the sampling frame, (iii) selecting the sampling method, (iv) determining the sample size, and (v) drawing a replacement strategy for rejection or lack of response.

For this study, the population included all households in the two service areas, comprising 596 *Grama Niladhari* (GN) divisions under 17 divisional secretariats (DS), and stretching across 3 districts (Table 5.1).¹ The study team identified the study population from a list of GN divisions provided by the Water Sector Reform Unit in the Ministry of Housing and Plantation Infrastructure and the NWSDB. The Sri Lanka Department of Census and Statistics verified this list to rule out any typographic errors in GN labels.

In selecting the sample, the team used a stratified random sampling approach in line with norms of good practice. First, they stratified the sample by GN division in order to have sufficient geographical coverage and spatial representation of the project area. They then calculated the number of households to be surveyed for each GN as equivalent to the ratio of each GN population to the total population in the area multiplied by the total number of surveys needed for each study area.

Table 5.1 Distribution of the Sample

Phase	District	Divisional secretariat	Number of Grama Niladhari divisions	Number of sample households
I	Gampaha	Negombo	38	324
		Katana	76	488
II	Kalutara	Panadura	14	46
		Kalutara	58	142
		Beruwala	77	190
		Dodangoda	10	22
		Mathugama	6	14
		Galle	22	31
	Galle	Balapitiya	34	66
		Elpitiya	12	23
		Baddegama	23	30
		Ambalangoda	23	46
		Hikkaduwa	81	117
		Galle	48	163
		Bope-Poddala	32	49
		Akmeemana	30	48
Habaraduwa	12	19		

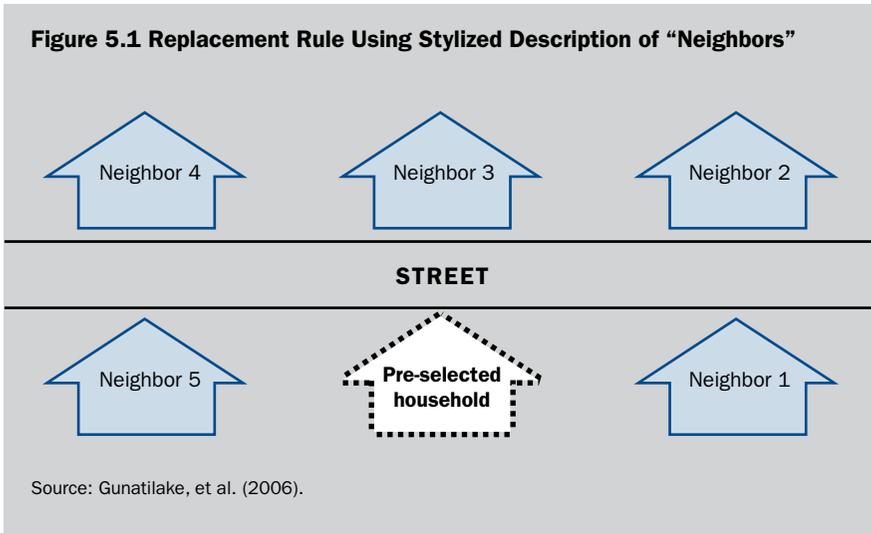
Source: Gunatilake, et al. (2006).

¹ The GN division is the smallest unit of administration in Sri Lanka, and is administered by a DS. A few DS units form a district.

Finally, random sample selection ensured that the sample was representative of the whole population, which allowed the team to generalize study findings. The team randomly picked the households from the pre-listing forms (also called F1 forms) for the 2001 Census of Population and Housing provided by the Department of Census and Statistics. Each F1 form represents a census block, consisting of about 80 houses or other buildings in the urban area and 60 in the rural area. On average, each GN division has 10 to 12 census blocks, depending on population density. Each F1 form contains summary statistics on population and housing units, household head's name and address, and a sketch map of the census blocks. The team then entered the selected households' information into an Excel file after translating the data from Sinhalese to English.

Having considered the available budget, different split sample tests, two service areas, the number of bids, and other important features of the study, the team chose a sampling size of 1,800 households. To be able to extrapolate the survey findings to the general population, the team decided to interview 1,000 households from Greater Negombo area (phase I of the survey) and 800 from Kalutara and Galle area (phase II of the survey).

The study team devised a geographical replacement rule for situations where it was impossible to interview the selected household after repeated attempts. Such a situation could arise if the selected household had moved, the Department of Census and Statistics had recorded the address incorrectly, or the household refused to participate in the interview. Under this replacement rule, a pre-selected household would be replaced with one of the five neighbors using a counterclockwise rule (Figure 5.1). That is, it would start from neighbor 1 to neighbor 5 until a replacement was found. In the unlikely event that none of these five replacements were available or willing to participate in the interview, the next candidate would be the next pre-selected household in the same GN. The study team prepared guidelines containing additional suggestions for enumerators in using judgment to maintain the random sampling process.



5.3.2 Designing Contingent Market Scenarios

A. Characterization of Existing WSS Situation

The team paid particular attention to the physical characteristics of the current supply, economic factors, environmental and health factors, and institutional aspects. This information helped the study team to properly define the commodity in the contingent market. Based on the initial preparatory work, the evidence suggested that a certain percentage of the population was connected to the piped water network. Hence, the commodity in question could be “an improvement in existing services” for this sub-sample in contrast to “a new service connection” for unconnected households. These two subgroups need different CV market versions and elicitation questions, because unconnected households need to pay a connection charge in addition to water consumption bills.

B. Commodity Definition

The proposed improvement in the water service came to be described as providing 500 liters of clean and safe water 24 hours a day, with regular and fair billing based on metered use, together with prompt repairs and efficient customer service.

C. Payment Vehicle

Monthly water bills and one-time connection charges were used as the payment vehicles.

D. Elicitation Question

In line with good practices discussed in Chapter 4, the present study used closed-ended CV questions to elicit household preferences (see Appendix 5.1).

E. Bid Distribution

The use of a closed-ended elicitation question meant selecting a set of bids to be offered to the households as monthly water bills and one-time connection charges. A number of factors were considered in selecting the bids. The bid (equivalent to a monthly water bill) distribution was chosen based on the information on current water bills, the cost of improved services, and other relevant information gathered through FGDs and purposive interviews. Based on secondary information collected through initial preparatory tasks, the team initially decided to set the range of bids at Rs. 75–1,500. These values were later modified based on FGDs and pre-tests (see below).

5.3.3 Designing the Survey Instrument

In preparing the survey instrument, as a starting point, the team used a CV study conducted earlier in Nepal (Whittington et al. 2002). The Nepal CV study was based on a selected set of modules from an exhaustive list described in the World Bank's manual for Living Standards Measurement Study Surveys (Grosh and Muñoz 1996). Based on the findings of the initial preparatory tasks and initial field work, the team modified the questionnaire of the Nepal study to suit local conditions in southwest Sri Lanka. The local counterpart team from the University of Peradeniya further revised all sections in the Nepal questionnaire to reflect physical and cultural conditions in the study area. The preliminary instrument was reviewed by RTI's internal review board to ensure that the procedures for collecting, storing, and analyzing the data did not pose risks to the human subjects. Given the subject matter of the study, the board determined that the proposal to administer a verbal consent (rather than written)

was adequate. The preliminary questionnaire for Sri Lanka eventually comprised the following sections:

- (i) Introductory Section and Environmental Priorities
- (ii) Water Sources: Quality and Quantity
- (iii) Water Treatment and Storage
- (iv) Sanitation and Sewerage
- (v) Contingent Valuation Elicitation Questions
- (vi) Debriefing Questions and Socioeconomic Profile.

The study team conducted FGDs and pre-tests to make the necessary revisions, and finalized the survey instrument with inputs from technical and policy experts.

5.4 Implementation and Data Management

5.4.1 Focus Groups

As described in Chapter 4, focus groups are structured brainstorming exercises involving individuals from the target population to learn about their opinions, perceptions, and reactions to the overall goals and specific contents of a survey. For the focus groups, the study team recruited individuals from the target population, including those with and without a private water connection and with varying economic and demographic backgrounds (e.g., age, gender, education, and socioeconomic status). Unlike typical CV studies that start with little or no background information, the team benefited from previous engineering and economic studies that assessed the water supply conditions and local people's willingness to pay (WTP) for improved water supply in the study area, including previous studies in support of the proposed intervention. Consequently, the team relied on only three conventional focus groups. The three FGDs solicited participants' reactions to the descriptions and questions from various parts of the survey instrument, particularly

the CV section.² Some of the main findings relevant to eliciting WTP for improved services are summarized as follows:

- (i) Wells were a primary and popular source of water supply in the coastal belt, serving as a substitute for piped water.
- (ii) Other than house connections, non-traditional alternatives to water supply include small-diameter mini-grids and metered stand posts.
- (iii) Distance to the network is a key reason for not connecting, and that distance was often correlated with distance to an all-weather road.
- (iv) Respondents are willing to look ahead and seriously consider the contingent commodity—improved water supply service—because many had heard of plans to expand the water supply network in their area.
- (v) Hours of service, health risk, regularity and predictability of billing, and efficient customer service were of particular concern. These features were included in defining the contingent commodity.
- (vi) About 100 liters of water per person per day appeared adequate. Water Board engineers confirmed that this was a reasonable assumption. Assuming an average family size of five, 500 liters per day were offered as part of the proposed water supply improvement.
- (vii) There were no strong reactions in favor of or against the range of monthly bill amounts (from Rs. 75–1,500 for a private connection) and the proposed connection charge of Rs. 6,000–12,000 seemed appropriate.
- (viii) Some participants drew attention to credit and finance needs, claiming that more people would connect if there were installment plans to cover the connection costs.
- (ix) The discussion on the institutional context for improved water supply suggested that there was likely to be an institutional effect in the measurement of WTP. Thus, the sample was split by two institutions—the private and the public sector.

² The first focus group was held in Unawatuna GN in Galle district, towards the southern tip of the study area, the second in Pilimatalawa GN in Kandy district, and the third in Kalutara North GN in Kalutara district. These three were supplemented with discussions with households and government officials. The final survey instrument reflected the FGD insights and findings.

5.4.2 Pre Tests

Based on the findings of the FGDs, the study team refined the survey instrument, which was in turn pre-tested on approximately 120 respondents drawn from the target population to identify any previously undetected problems. Respondents consisted of a mix of households, including those with and without connections to the piped water network.

Pre-tests were conducted in three areas: Negombo, Peradeniya, and Kalutara. Pre-tests helped identify problems with the content, length, and flow of the preliminary survey instrument. Equally important, pre-tests allowed the team to further train the enumerators. They also helped set up the logistics of implementation such as the formation of groups, the assignment of field supervisors, and plans for travel. On average, the interviews lasted 60 minutes with the most recent ones considerably shorter (the minimum was 40 minutes and the maximum 180 minutes), mostly as enumerators became more familiar with the instrument and could better navigate the various sections. Based on the results of the pre-tests, the following refinements were made to the survey instrument:

- (i) The most important contribution of the pre-tests was to set the range for the monthly bids. The basic aim was to find a bid low enough to be accepted (for connection) by all households. This was determined to be Rs. 100 per month for house connections. At the upper end, the task was to find a monthly bill high enough to be rejected by about 90%–95% of the respondents. Based on the pre-tests, the high-end bill (Rs. 1,500) was found to be too high and was therefore lowered to Rs. 1,000 per month.
- (ii) The pre-test also revealed that the description of the CV scenario was too detailed. The team therefore shortened it, made it more focused, inserted opportunities for conversation, and requested enumerators to use these opportunities.
- (iii) In response to suggestions from the NWSDB, the team modified the water treatment questions to ask for reasons from the households who said they were not treating their water.
- (iv) Based on the pre-test responses, it was concluded that the alternative options for private water connections were (a) small-diameter mini-grids, (b) metered stand posts, (c) publicly provided dug wells, and (d) small-scale independent retailers.
- (v) The team found it important to improve the instructions within

the survey to direct the enumerators to the four different versions of the CV section.

There were no major changes to the basic structure of the instrument as used in the pre-tests, other than splitting the socio-demographic module into two sections namely: (i) family and health, and (ii) socio-economic. Several changes were made to the wording, structure, and location of questions in the survey. Every translation required a couple of passes before the ideas could be communicated simply. The team also incorporated inputs from the enumerators.

The sample was split into connected and unconnected households. For the CV question, these groups were further subdivided into those who would be supplied by the public sector and those by the private sector. Unconnected households were given two elicitation questions: one on monthly bills and the other on connection charges. The sample was also split into two study areas. The following is a sample elicitation question from the survey instrument for a connected household under private provision:

Suppose your household receives 24-hour water supply service of 500 liters per day, with water that is safe to drink directly from the tap, accurate billing of the water with reliable and responsive customer service by a private service provider. Are you willing to pay Rs. 200 water bill per month? (1) Yes (2) No

5.4.3 Enumerator Training

The team employed 15 enumerators to carry out the CV survey. The enumerators were selected from a pool of recent undergraduates of the University of Peradeniya, with a background in agricultural economics, economics, or agricultural sciences. As expected, most were not experienced in large-scale survey administration, particularly one that involved stated preference questions (contingent valuation and conjoint analysis). Therefore, enumerator training became a critical element of the project in two ways. First, it allowed the enumerators to become familiar with the survey instrument, especially the intricate details in each section. Second, the training served as a form of focus group and helped the team refine the wording and flow of the questions.

Enumerators were trained during a 10-day, two-stage training session with a mix of lectures, role playing, and field trials. The first stage of the training was undertaken primarily at the University of Peradeniya campus. Classroom sessions held over several days introduced the enumerators to the basic elements of the study and its relevance, economic concepts underlying the study, the importance of key questions, and how the data would be interpreted. In addition, an introduction to the first four modules was provided to the enumerators: (1) Introduction (2) Current Water Sources (3) Water Treatment, Storage and Hygiene Practices and (4) Household Sanitation Service.

After reviewing and discussing the key questions, role plays for the modules were conducted between sets of two enumerators, i.e., one enumerator would administer the survey to the other and vice versa. The enumerators then conducted two sample interviews in the Kandy area with the first four modules.

The second stage of the training was conducted in Negombo to enable the enumerators to familiarize themselves with the study area. The entire team (including principal investigators, field coordinators, and enumerators) moved to Negombo for 4 days, and followed a similar pattern of classroom lecture, discussions, and role playing for the remaining modules, namely: (5) Contingent Valuation of Improved Water Supply, (6) Family Roster, and (7) Socioeconomic Profile. Enumerators then conducted 2 days of trial interviews with randomly chosen subjects in the Negombo area and one day in the Kalutara-Galle strip (around the town of Wadduwa). Care was taken to expose all enumerators to a range of interviewees including at least one specially sampled poor household. The early training interviews lasted between 1 and 3 hours.

Questions raised during lectures, role playing, and discussions as well as feedback from training interviews were used to develop guidelines for survey implementation. The guidelines discussed the purpose of specific questions and helped develop a common understanding of how to ask certain questions and preferred ways of coding the responses in the questionnaire. In addition to guidance on how to interpret certain questions, the guidelines reiterated the intent of the critical questions in each module. For example, in the module for WTP, it was emphasized that enumerators should read out the complete scenario for the question, and not offer their own version of what they thought. This would ensure that all respondents received identical descriptions of the proposed service, allowing the team to compare their responses.

Besides training on the survey instrument, a separate session was held in Negombo to orient both the field coordinators and enumerators on the collection of spatial data. Interviewers were introduced to the rationale behind mapping household locations as well as infrastructural and environmental amenities and disamenities. All team members were trained in the use of GPS instruments and tested independently for their ability to use the instruments and to mark the sample households.

Another important element of the training focused on developing standards for concepts such as volume of water collected and distance traveled. Accordingly, enumerators were trained to visually assess water container volume. Their estimates, based on the range of buckets and pots of sizes commonly used for water storage, were calibrated to the actual volumes. Estimates were also made on the reasonable quantity of water that was likely to be carried in buckets of certain sizes, as opposed to their full nominal values (e.g., a 20-liter bucket is unlikely to hold more than 17 liters when used for ferrying water). Distance estimates were similarly calibrated with the actual distances in travel time by foot and in kilometers.

5.4.4 Implementation of CV Study

A. Survey Administration

One principal investigator (PI) served as the overall person-in-charge of survey implementation. The PI was assisted by three field coordinators who were directly responsible for all logistical aspects of field implementation as well as coordinating enumerators. The three field coordinators were integral to the implementation of the survey. They handed out blank survey forms each morning, facilitated field operations periodically, randomly monitored interviews for quality assurance, and collected each day's completed surveys. In rare cases they re-scheduled interviews with Tamil-speaking households who did not understand Sinhalese, arranging for Tamil-speaking enumerators to visit.

Besides these responsibilities, the field coordinators also checked each survey for completeness and accuracy according to a quality checklist. If any discrepancies were detected, the enumerators had to return to the households to correct the errors or fill in the missing information. In addition to the review conducted by the field coordinators, the PI conducted a second round of reviews of surveys. The team also

maintained a log of completed surveys on a daily basis. This provided an overview of the progress of the survey administration.

Collectively, these measures ensured that mistakes were spotted and corrected at an early stage, thereby setting a high standard for quality control and reducing errors. These measures avoided the need for repeated visits to the households as the survey progressed. On average, the enumerators altogether completed about 65 surveys per day, and the interviews ran for about 45 minutes.

B. Data Management and Preliminary Analysis

i. Data Entry and Processing

While the survey was progressing in the field, a coding sheet and template for data entry were prepared. The data recorded on the questionnaires were entered into the selected data management software, using codes developed during the survey design.

Three quality assurance and quality control procedures were employed to ensure that data were inputted accurately: range checks, intra-record checks, and final consistency check. Range and intra-record checks were undertaken during data entry. By building a proper data entry template, the operators were only allowed to proceed to the next question if the data for the current question fell within the allowable range of responses for each question. An intra-record consistency check was administered immediately after entry of each questionnaire and a final scan for overall consistency was conducted when all questionnaires had been entered. This final consistency check ensured that values from one question were consistent with values from another question.

In addition, spot checks on the data entry operation were conducted and 10% of the surveys were double-entered. In addition, 100% of critical modules such as WTP elicitation response were double-entered to ensure that there were no discrepancies between the hard copies and the electronic data set.³

ii. Descriptive Statistics

To ensure quality, descriptive statistics of the key variables were estimated and examined. Particular attention was paid to identify

³ “Double-enter” means that a different person enters the data from the selected questionnaires (or modules) onto a separate Excel sheet. The two Excel sheets (original and double-entered) are compared electronically to determine whether the original sheet accurately recorded the responses from the questionnaires.

anomalies, outliers, and improbable values. In presenting the descriptive statistics, it was useful to identify subpopulations of policy interest. This study used the subpopulations of: (i) WSS user type (private water connection or public tap); (ii) socioeconomic group (households by expenditure quintiles); and (iii) subregions of the study area (administrative units). Data on household consumption expenditure were compared against income, wealth and assets, caloric intake, demographics, and housing quality to validate the quality of the data. Cross-tabulations by socioeconomic, geographic, and current user status were calculated for all important variables.

These analyses provided a summary of the profile of the study population and enabled the study team to gain confidence in the reliability of the survey data. Descriptive statistics can be presented in different ways and Table 5.2 shows the set of variables selected to represent the WSS and socio-demographic profile in the study area.

Table 5.2 Selected Demographic and Socioeconomic Variables of Sample Households

	First quintile (n=365)	Fifth quintile (n=362)	Overall (n=1,818)
Demographics and socioeconomics			
Family size	5.8	3.7	4.8
% Sinhalese	85	91	89
% Buddhist	65	56	62
Household head's education attainment (years)	8	10	10
Housing conditions			
% single family and single story	79	90	86
% multi-family and single story	18	2	10
Monthly consumption (Rs.)	11,883	32,308	25,411
Monthly per capita consumption (Rs.)	2,614	10,310	5,294
% living on less than \$ 1 a day	67	0	13
Distance to infrastructure			
Piped water network (kilometers)	0.25	0.1	0.2
Main road (kilometers)	0.2	0.1	0.1
Total water consumption (m3)	19	27	22
% have a private tap	28	43	38
% have a private well	59	69	66

continued on next page.

Table 5.2 continued.

Table 5.2 Selected Demographic and Socioeconomic Variables of Sample Households			
Demographics and socioeconomics	First quintile (n=365)	Fifth quintile (n=362)	Overall (n=1,818)
% use water-sealed toilet	90	99	96
% use pit latrine	3	0	1
% use neighbor's toilet	6	0	3

n = number of households.
Source: Pattanayak et al. (2004b).

5.5 Results

5.5.1 Validity Tests and Estimating Mean WTP

As discussed in Chapter 4, the analyst can establish the accuracy of CV studies by evaluating the survey responses based on three characteristics: reliability, precision, and validity. Given the large sample size used in this study, precision should not be a concern. Since the study took measures to minimize biases throughout the process—study design, enumerator training, instrument preparation, FGD and pre-test, and data entry—the potential for bias was expected to be very low.

Chapter 4 also referred to two types of validity: convergent and construct validity. For many project preparatory CV studies, including this one, it is not feasible to determine convergent validity. In a study of this nature, however, the construct validity can be readily checked by estimating a WTP function that relates responses to the individual's characteristics and the characteristics of the commodity concerned.

Hypothesis testing can then be performed using the WTP function to examine construct validity. Since this study used a closed-ended (or dichotomous choice) elicitation question, hypothesis testing used a multivariate probit regression model. In this model, the household's reply (1 = yes, 0 = no) to the dichotomous choice elicitation question serves as the dependent variable. The independent variables consist of the bid; a set of economic variables (poverty status, connection cost); household data (including location and distance to a road); availability of alternative

sources of water; occurrence of diarrhea in the family; education level of the household head; and household perception-related variables such as perception of water pollution and degree of water scarcity in the area. Other variables were added based on the focus group comments, including the form of provision whether public or private. The results of the probit model are given in Table 5.3.

Table 5.3 Determinants of Demand for Improved Piped Water Service: Probit Regression

Variable	Mean	Coefficient	P-Value
Regression constant		1.119 **	0.000
Monthly consumption charge (Rs.)	487	-0.002 **	0.000
One-time connection cost (Rs.)	5,534	-0.00003 **	0.004
Monthly per capita consumption (Rs.)	6,044	0.00003 **	0.004
Household receives remittance (1 = yes; 0 = no)	0.10	0.276 **	0.013
Household is a Samurdhi recipient (1 = yes; 0 = no)	0.19	-0.245 **	0.012
Household head is employed in private sector (1 = yes; 0 = no)	0.41	0.213 **	0.002
Distance to road (kilometers)	0.32	0.112	0.134
Household resides in Greater Negombo (1 = yes; 0 = Kalutara or Galle)	0.45	-0.484 **	0.000
Household resides in Kalutara (1 = yes; 0 = Greater Negombo or Galle)	0.23	-0.326 **	0.000
% of households with access to private wells in Greater Negombo	0.79	-0.329 **	0.014
% of households that consider water quality of their alternative sources as excellent or good in Greater Negombo	0.59	-0.312 **	0.013
Household believes that there is a water contamination problem (1 = yes; 0 = no)	0.10	0.248 **	0.023
Household thinks government should give connection subsidy to low-income households for improved water supply services (1 = yes; 0 = no)	0.30	0.025	0.731

continued on next page.

Table 5.3 continued.

Table 5.3 Determinants of Demand for Improved Piped Water Service: Probit Regression			
Variable	Mean	Coefficient	P-Value
Household is particularly conscious of institutional issues (1 = yes; 0 = no)	0.01	0.570 **	0.040
Private sector will provide improved service (1 = yes; 0 = public sector will provide)	0.55	−0.116 *	0.085
Household is particularly conscious of health issues (1 = yes; 0 = no)	0.02	0.648 **	0.003
Household has experienced a case of morbidity event (1 = yes; 0 = no)	0.02	0.649 **	0.006
Household is Tamil (1 = yes; 0 = no)	0.03	−0.475 **	0.047
Household owns the house (1 = yes; 0 = no)	0.94	−0.322 **	0.025
Education of household head (years)	9	0.021 *	0.090
Number of observations		1,735	
Likelihood ratio statistic χ^2 (20)		389	0.000
% responses that are correctly predicted		73	
Log likelihood		−942	

** indicates significance at $\alpha=0.05$, * indicates significance at $\alpha=0.10$.
Source: Gunatilake, et al. (2006).

The results in Table 5.3 show behavioral responses consistent with economic theory. As expected, demand for improved water services decreases as the monthly water bill increases. Similarly, higher connection costs reduce WTP. Moreover, the results show a positive income effect as WTP is lower among poor compared to non-poor households.⁴ Those who receive remittances from abroad are willing to pay more while *Samurdhi* (Sri Lanka’s flagship poverty alleviation program) recipients have a lower WTP. Those who consume more water are willing to pay more. The availability of water substitutes—in this case mainly wells with good quality water—as expected, has a negative effect

⁴ Poor households were defined as those households in the bottom quintile in terms of monthly per capita consumption. The threshold worked out to Rs. 3,356 per capita. By this definition, 365 of the sampled households (1,735) were deemed poor.

on WTP. A negative and significant institutional provision variable shows that private sector provision of water is not well received by consumers.⁵ The dummy variable related to location indicates that there are location differences in WTP.

These results provide a high level of confidence about construct validity and, consequently, about the estimated mean WTP derived from the probit model. This implies that respondents understood the contingent market scenarios and responded accurately, so the findings of the study are sufficiently robust for policy purposes.

Upon validating the accuracy of the CV data, the team used the regression results to estimate the mean WTP. As discussed in Chapter 4, the probit regression results do not provide WTP directly. The mean WTP can be estimated using the coefficients of this regression model.⁶ The mean WTP for the entire sample was calculated at Rs. 270 per month. For selected sub-samples, the mean WTP was calculated at Rs. 357 per month for the non-poor and Rs. 106 per month for the poor. The mean WTP for those connected to piped water was about 3 times higher than that of the unconnected. Given the pre-existing average tariff of Rs. 75 per month for a household, the mean WTP for an improved service (of Rs. 270) was much higher, indicating that there is large effective demand for this project. However, the analyst should not rely exclusively on the mean WTP values, because mean values may be misleading as a guide to actual tariff setting because the tariff should be lower than WTP and there is a vast difference in WTP among different groups.

5.5.2 Assessing Effective Demand

This section illustrates how the CV data can be used to assess effective demand for WSS services. Using a single-bound, closed-ended CV question to elicit household preferences, the study asked households currently connected to piped water services to consider an increase in monthly consumption charges for improved water supply service. In addition to paying monthly consumption charges, households without access to

⁵ In contrast, Whittington et al. (2002) find that private sector involvement increased WTP values, implying that consumers in Nepal have less confidence in government-run water services.

⁶ For all variables in Table 5.3, including the regression constant but excluding the monthly consumption charge and connection charge, the mean is multiplied by the coefficient. The sum of the products is then divided by the coefficient on the monthly consumption charge (-0.002). Section A4.2.1 of Appendix 4.2 illustrates a slightly different procedure for the calculation.

piped water were asked additional questions on connection charges. Based on the proposed improvement, the survey sought consumer responses, either “yes” or “no”, to different water bills for improved water services. Table 5.4 shows that 83% of connected respondents and 57% of unconnected respondents answered “yes” when they were presented with the improved service with a Rs. 100 monthly bill.⁷ As the bid amount increased, the percentage of respondents (both connected and unconnected) answering “yes” gradually dropped.

Table 5.4 Distribution of “Yes” Responses to Closed-Ended CV Question

Water bill (bid) for improved service (Rs.)	Connected (%) (n=680)	Unconnected (%) (n=1,138)
100	83	57
200	74	36
300	63	35
400	47	29
500	42	28
600	29	22
800	33	9
1,000	14	15
Total	49	29

CV = contingent valuation, n = number of households.

Source: Gunatilake, et al. (2006).

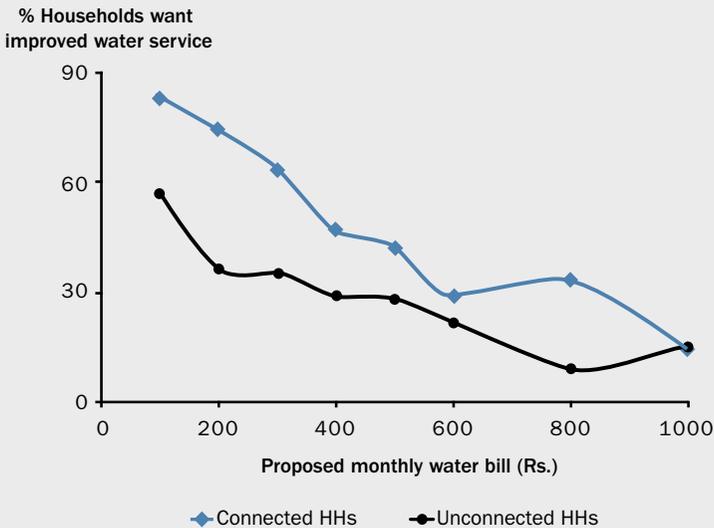
The responses to the elicitation question can be used to gauge the effective demand for improved water supply and sanitation services (Table 5.4). Demand analysis shows the relationship between price and quantity demanded and, as shown in Figure 5.2, a similar price–quantity relationship can be obtained from the responses to the elicitation question in Table 5.4.⁸ Figure 5.2 illustrates that, as expected, as the bid (monthly water bill) increases, acceptance (“yes” answers) by both connected and unconnected households decreases. However, acceptance of the bid is higher among those who are currently connected to piped

⁷ Unconnected households receive a connection charge together with the monthly bill. These connection charges were randomly assigned among the monthly bills.

⁸ Note that the y-axis here represents the percentage of households accepting a bid, and is therefore slightly different from the usual quantity measure. However, the percentage of households accepting a bid is a good proxy for the quantity demanded. Using average consumption data, these percentages can be readily converted to quantities.

water compared to those unconnected. This seems counterintuitive in that, usually, unconnected households might be expected to be willing to pay more because the economic cost of water (through direct purchase, time spent in collecting, or as expenditure on water-related diseases) for unconnected households is generally higher than that of connected households (UNDP 2006).

Figure 5.2 Household Demands for Improved Water Service in Sri Lanka



HH = household.

Source: Pattanayak et al. (2004b).

In this study, however, the situation is different for two reasons. One is the availability of cheap and good quality substitutes, mainly well water, and the other is the affordability of connection charges. As will be shown later, excluding the connection charge substantially increases the unconnected households' WTP. Segregating the sample further into poor (first income quintile) and non-poor (fifth income quintile) groups shows substantially higher "yes" responses among the non-poor for both connected and unconnected groups.

Data organized as in Table 5.4 and Figure 5.2 is useful in summarizing information on demand in response to changes in charges. For example, if the monthly water bill is Rs. 200, about one-third of households currently without a private tap will be connected. If the water bill goes

up to Rs. 400, then almost 30% of households without an individual tap would be connected. Thus the information generated through a CV study can be used in predicting effective demand for proposed WSS services under various combinations of prices and incomes.⁹ Such predictions enable the analyst to provide feedback to project engineers on optimal plant capacity.

Simulations are generally performed using income as a policy variable. Sometimes, a proxy for income may be needed when accurate income data are difficult to obtain. Proxy variables can be the number or value of the assets a household possesses and monthly household expenditure. This study uses poverty as a proxy:¹⁰ the sub-sample of poorest and richest were separated and their uptake rate was separately estimated.¹¹

Table 5.5 shows the predicted uptake rates (or rates of acceptance) for two income groups (poor and non-poor). The results indicate that the predicted uptake rates are much lower than anticipated.¹² This cast initial doubts on the viability of the proposed PPP since the PPP designers assumed that 95% of the population would get individual water connections. The investment plan; hours of supply; and consequently the capacity of the plants, revenue levels, and subsidy requirements were all dependent on this assumption. Removal of the connection charges showed a significant increase in uptake rates. Even with no connection and monthly charges, however, about 30% of the poor did not want to get connected. This implies that poor households may have a good substitute for piped water or they may be incurring certain implicit transaction costs when getting individual water connections.¹³

⁹ Similar analysis using prices and income for wastewater and solid waste projects are presented in Chapter 6.

¹⁰ See footnote 4 of Chapter 5 for the definition of poverty.

¹¹ In predicting the uptake rates, the mean value of the monthly bill for connected households and mean values of monthly bills and connection charges for unconnected households were used.

¹² The uptake rates in Table 5.5 show the percentage of households in each category that are willing to get the connection/remains connected to receive improved water service with increased bills.

¹³ These transaction costs may be due to bureaucratic red tape or petty corruption involved in getting water connections.

Table 5.5 Predicted Uptake Rates of Improved Water Supply for Poor and Non-Poor

Service area	Uptake rates (%)	
	Poor	Non-poor
Greater Negombo		
Connected	49	64
Unconnected	32	47
Kalutara-Galle		
Connected	44	59
Unconnected	27	42

Note: Poor households are defined as the bottom quintile of the sample and the non-poor are the upper quintile based on monthly per capita consumption.
Source: Gunatilake, et al. (2006).

5.5.3 Use of WTP Estimates and Policy Simulations

CV studies can help decision making on projects in different ways. In addition to the use of CV findings to assess the effective demand for improved water services, the mean WTP estimate can also be used to estimate benefits in cost–benefit analysis.¹⁴ Different types of policy simulations can also be undertaken depending on the study objectives and project-specific issues.

The study used the probit regression results (in Table 5.3) to analyze a number of policy issues related to designing improvements in WSS, such as the choice of provider, design of spatially-based pro-poor service delivery, determination of affordability, and characterization of low WTP groups. To assess households' preferences toward the provider, the study used a split sample approach. Approximately half of the sample was told that the improved service would be provided by the private sector, while the rest were told that the reformed public sector would improve the service. A dummy variable was used to analyze households' attitudes toward the service provider.

The statistically significant negative coefficient for the question relating to private sector provision (see Table 5.3) indicates that, holding everything else constant, households will have a lower probability of connecting to the water supply if this is provided by the private sector.

¹⁴ It is used in this manner in Chapter 6 for water, wastewater, and solid waste.

This shows that households' perceptions are against generally held beliefs on the desirability of private sector provision of WSS.¹⁵ Therefore, an analysis of the reasons for household preferences for public or private sector service provision may be necessary to ensure success of WSS projects where PPPs are involved.

The study also examined the possibility of designing pro-poor service delivery. To do this, the WTP for each household in the sample was calculated using the regression model in Table 5.3.¹⁶ Mapping of surveyed households by GPS allowed the investigation of any low WTP clusters or any other type of spatial patterns or clustering of WTP. Poverty maps were drawn for the two service areas using the survey data and the poverty definition. These maps were overlaid with WTP maps to examine whether there was any particular pattern that could be used to design spatially-based, targeted pro-poor service delivery. As the maps did not show any distinct spatial clustering, there was no basis to identify localities with a high intensity of poverty and low WTP. Therefore, the design of pro-poor service delivery was not feasible in this case.

To assess affordability, the study performed simulations using a one-time connection charge as the policy lever. The impact of connection charges on WTP was evaluated by simulating an econometric model with different levels of connection charges.¹⁷ Tables 5.6 and 5.7 show WTP for improved water services from a private provider for both connected and unconnected households, segregated further into poor and non-poor groups.¹⁸ The simulation results in Table 5.6 assume zero connection fees for currently connected households and a Rs. 6,000 one-time fee for those unconnected, while Table 5.7 assumes zero connection fees for all households. Thus, the differences in WTP of the two tables are due to connection charges. Comparing these tables clearly shows that WTP is significantly higher if the connection charge is set at zero. WTP is very low among unconnected households when they have to pay connection charges. In the absence of any connection subsidy, low willingness to connect to the new system could compromise the financial viability of the proposed PPP.

¹⁵ In their review of a number of studies, Gunatilake and Carangal-San Jose (2008) show that there is no evidence that privately operated water utilities are more efficient.

¹⁶ By incorporating the household data into the WTP function and using the same method described in Appendix 5.3, one can estimate WTP for each household in the sample.

¹⁷ Appendix 4.2 explains how this type of simulation is performed.

¹⁸ The simulation was performed with a different, simplified regression model. Therefore, the WTP values in Tables 5.6 and 5.7 are only indicative.

Table 5.6 WTP with Connection Fee (Rs./month)

District	Poor (n=365)	Non-poor (n=362)	Overall (n=1,818)
Greater Negombo	105	250	150
Connected	215	515	425
Unconnected	10 *	145	55
Kalutara-Galle	180	470	310
Connected	255	490	405
Unconnected	120	385	200
Overall	160	390	250
Connected	245	500	410
Unconnected	100	215	115

n = number of households, Rs. = rupees, WTP = willingness to pay.

* From a few households in Katana area.

Note: Estimation based on no connection fee for currently connected households and Rs. 6,000 fee for unconnected households. All figures are median WTP

Source: Gunatilake, et al. (2006).

Table 5.7 WTP without Connection Fee (Rs./month)

District	Poor (n = 365)	Non-poor (n = 362)	Overall (n = 1,818)
Greater Negombo	215	505	400
Connected	215	515	425
Unconnected	210	500	385
Kalutara – Galle	310	550	440
Connected	255	490	405
Unconnected	320	745	480
Overall	290	520	425
Connected	245	500	410
Unconnected	300	570	430

n = number of households, Rs. = rupees, WTP = willingness to pay.

Note: Estimates based on no connection fee for currently connected households or unconnected households. All figures are median WTP

Source: Gunatilake, et al. (2007).

Other simulation exercises also revealed a number of characteristics pertaining to a subgroup of households that have a lower WTP, namely that they are: (i) currently unconnected, (ii) poor, (iii) happy with the quality of the existing water source, (iv) house owners, and

(v) less educated. Underlying these characteristics is mainly the issue of affordability. In addition, this subgroup also has a reliable system of self-provision of water. Their WTP for improved water service is also influenced by lower incidence of water-related diseases and the lack of a perceived link between personal health and water quality. As a result, these findings show that there is much less demand for improved WSS in the study area than anticipated by the PPP designers.

5.6 Unbundling the Demand: Conjoint Analysis

Many CV studies in the past have focused almost exclusively on fees/charges as the primary factor that determines demand for WSS. However, there is emerging evidence from other service industries that, besides charges, consumers value multiple service attributes (Eto et al. 2001). The elicitation question used in this study to estimate WTP describes improved water supply service as a composite commodity with five attributes: (i) cost (monthly water bill); (ii) quantity (500 liters per day); (iii) quality (safe to drink directly from the tap); (iv) reliability (duration of supply, 24 hours a day); and (v) service quality (regular and fair billing based on metered use, together with prompt repairs and efficient customer service).

In the elicitation question, these attributes are fixed at levels taken to reflect household preferences. The estimated WTP values, therefore, do not reveal household preference for different levels of these attributes, but correspond to the fixed level for each attribute. The assumptions on the attributes, however, may not necessarily be realistic or representative of all the households.

This section describes how WTP can be estimated for each attribute through the use of a variant of the CV method called conjoint analysis. This means that demand can be unbundled to different attributes to allow the design of better service delivery, balancing the costs of providing different levels of attributes with the tariff, and enhancement of demand for improved WSS.

Conjoint analysis was originally used in marketing research to value different attributes of a commodity. It has become increasingly popular, in part due to the validity concerns identified in some CV studies and

the additional information it can provide for policy purposes. Conjoint analysis treats commodities as a combination of a series of attributes offered at varying levels.¹⁹

The first step in undertaking a conjoint analysis is to define the attributes of the commodity in question and the preferred levels households wish to consume. For this study, the relevant attributes identified were the monthly water bill (cost), hours of supply, water quality, volumetric consumption, and service alternatives. These attributes were chosen based on the findings of focus group discussions, interviews with households, and meetings with relevant government officials. Table 5.8 presents the attributes and their levels used in the study.

Table 5.8 Water Supply Service Attributes and Levels

Attribute	Levels	Level		
Service option	Private water connection	Small diameter mini-grid	Metered stand post	
Consumption volume	600 liters per day	200 liters per day	200 liters per day	
	800 liters per day	600 liters per day	400 liters per day	
	1,000 liters per day	1,000 liters per day	600 liters per day	
Supply hours	12 hours a day	4 hours a day	4 hours a day	
	16 hours a day	12 hours a day	8 hours a day	
	24 hours a day	24 hours a day	12 hours a day	
Safety	Straight from the tap	Straight from the tap	Only after boiling	
	Only after filtering	Only after boiling	Only after filtering and boiling	
	Only after boiling	Only after boiling, filtering and treating	Only after boiling, filtering and treating	
Monthly water bill	Rs. 200	Rs. 25	Rs. 25	
	Rs. 500	Rs. 100	Rs. 50	
	Rs. 800	Rs. 600	Rs. 100	

Source: Gunatilake, et al. (2006).

The next step in conjoint analysis is to develop an appropriate experimental design. The attributes and levels together give a large number of choice sets. The entire choice set can be too large to be accommodated in a conjoint study. Moreover, certain choices can be

¹⁹ See Adamowicz et al. (1999) for a description and Yang et al. (2006) for an application to WSS.

meaningless. For example, a 24-hour supply of the highest quality water at the highest consumption level together with the best service quality cannot be provided with a low monthly bill. Such incompatible choices should be removed from the conjoint experiment. The experimental design selects a subset of choices to be used in the conjoint experiment. In this case, a D-optimal experimental design was used.²⁰ Table 4.9 shows a sample conjoint question derived from the experimental design.

Table 5.9 A Sample Conjoint Analysis Question

	Alternative 1	Alternative 2	Alternative 3
Service option	Private water connection	Small diameter mini-grid	Metered stand post
Liters per day	800	1,000	600
Supply hours per day	24	4	8
Safe for drinking	After boiling	Straight from the tap	After filtering, boiling, and treating
Monthly water bill (Rs.)	500	100	50
What do you think your household would do? a. keep connection to the water supply network, b. connect to the small diameter mini-grid, c. rely on the metered stand post, or d. would you choose none of the above and continue to use your present water sources?			
Source: Gunatilake, et al. (2006).			

One advantage of conjoint questions over a basic CV question is that it can extract more information from the same sample, as it provides more than one choice to a household in an interview. In this study, there were 27 unique tradeoffs grouped into 9 blocks; each respondent was presented with one block of three choices with four levels of attributes each. Thus, sample respondents answered 5,404 questions, which generated 21,616 observations, compared to 1,735 observations generated by the CV question in Table 5.3. The responses for the given choices were modeled using a conditional logit model to estimate WTP for each attribute. Table 5.10 shows the results of the conditional logit model.

²⁰ This design minimizes the geometric mean of the covariance matrix of the parameters of the conditional logit regression model to be estimated, to analyze the conjoint data and to estimate WTP for each attribute; see Zwerina (et al. 1996) for details.

Table 5.10 Attributes of Service Alternatives: Conditional Logit Model for Conjoint Analysis

Variable	Mean	Coefficient	P-value
Proposed monthly water bill (Rs.)	216	-0.003	0.000
Volume of water per day (liters)	450	0.0004	0.000
Hours of water supply per day (number of hours)	10	0.039	0.024
Squared hours of water supply per day	161	-0.001	0.053
Water is safe for drinking straight from the tap (1 = yes, 0 = no)	0.18	0.840	0.000
Water is safe for drinking only after filtering (1 = yes, 0 = no)	0.08	0.468	0.000
Water is safe for drinking only after boiling (1 = yes, 0 = no)	0.23	0.396	0.000
Water is safe for drinking only after filtering and boiling (1 = yes, 0 = no)	0.08	0.246	0.037
Private tap dummy (1 = yes, 0 = mini grid or stand post)	0.25	1.223	0.000
Mini-grid dummy (1 = yes, 0 = private tap or stand post)	0.25	1.058	0.000
Household chooses to opt out (1 = yes, 0 = no)	0.25	2.005	0.000
POOR*Proposed monthly water bill	43	-0.001	0.030
POOR*Volume of water per day	90	0.00005	0.834
POOR*Hours of water supply per day	2	-0.0002	0.997
POOR*Squared hours of water supply per day	32	-0.0001	0.924
POOR*Water is safe for drinking straight from the tap	0.04	-0.019	0.915
POOR*Water is safe for drinking only after filtering	0.02	0.272	0.322
POOR*Water is safe for drinking only after boiling	0.04	0.128	0.408
POOR*Water is safe for drinking only after filtering and boiling	0.02	-0.107	0.636
POOR*Private tap dummy	0.05	-1.081	0.000
POOR*Mini-grid dummy	0.05	-0.581	0.000
POOR*Household chooses to opt out	0.05	-0.492	0.080
Number of observations		21,616	
Likelihood ratio statistic $\chi^2(11) / \chi^2(22)$		2464	0.000
Log likelihood		-6260	

Source: Gunatilake, et al. (2006).

Overall, the results of the conjoint analysis confirm that besides monthly charges, household demand is influenced by other service attributes. The signs on the different coefficients indicate whether household welfare or utility is positively or negatively affected by each attribute. As expected, a higher monthly bill generates negative utility for the households. Volume of water and number of supply hours increase their utility; however, hours of supply show diminishing marginal utility as indicated by the negative coefficient of the squared term. As expected, the quality of water has a positive impact on utility. Among the service options proposed, private taps and mini-grids are preferred over public stand posts. More interestingly, the results show that about 45% of households prefer their current source in comparison to all the proposed options. This finding further confirms that the demand for improved water services was much less than originally anticipated.

In order to examine whether the preferences differ among the poor and non-poor, a set of dummy variables was used in the regression model (1 = poor, 0 = non-poor). The results show that there is a difference in overall preferences between the poor and non-poor. However, preferences do not differ for certain attributes. The poor have higher marginal utility of income, and for the cost involved prefer stand posts over private taps and mini-grids over public taps. The poor's preference on hours of supply, volume, and safety, however, is not different from the non-poor.

The conditional logit model can also be used further to calculate the marginal WTP (MWTP) for each attribute. As with mean WTP, the estimated coefficient for the attribute can be divided by the coefficient of the monthly bill (reflecting the estimated marginal utility of money) and multiplied by -1 to obtain the mean MWTP. For example, MWTP for an increase of supply by one liter is Rs. 0.133 given as $0.0004/(-0.003) \times -1 = 0.133$

Table 5.11 shows the MWTP for different attributes. Given that the mean is close to the current volumetric consumption of water, additional supply should have a low MWTP, as shown by the results. Hours of supply also has a relatively low MWTP. Thus, in combination, these results indicate that a 24-hour supply, as perceived in the design of the PPP, may not be in much demand. Instead, households are willing to pay relatively large amounts for water quality as indicated by the MWTP results. The lowest quality (drink only after treating, filtering, and boiling) was taken as the reference point in the dummy variable analysis. As the water quality increases, MWTP gradually increases and a household is willing

to pay Rs. 280 per month, on average, for the best quality water, all else remaining constant.

Table 5.11 MWTP for Different Attributes of WSS

Attribute	Mean	Marginal WTP, Rs.
Water volume (liters)	450.00	0.13
Hours of supply (hours per day)	10.00	13.00
Water quality		
Straight from the tap	0.18	280.00
Only after filtering	0.08	156.00
Only after boiling	0.23	132.00
Only after boiling and filtering	0.08	82.00

WSS = water supply and sanitation, WTP = willingness to pay.
Source: Gunatilake, et al. (2006).

The foregoing results demonstrate the usefulness of conjoint analysis in understanding consumer preferences better. The results show clearly that household preferences do not depend only on the monthly charges, but on a variety of attributes of the WSS service. Some attributes are equally preferred while other attributes are preferred differently by the poor and non-poor. Service programs with similar attributes of volume, hours of supply, and safety can be provided to both poor and non-poor groups since there is no statistically significant difference in their responses.

Moreover, the findings of conjoint analysis can be used to make informed decisions on service delivery design. For example, it is clear that households do not value a 24-hour water service. Therefore, designing a water supply scheme with this in mind would have wasted resources. The study shows that households' WTP is small for additional water volumes and service hours, but significantly higher for water quality. The lesson is that service providers should ensure that water is provided at good quality for which consumers are willing to pay more. Because a water utility incurs various costs in providing different attributes at various levels, designing the service delivery according to what consumers prefer will help avoid unnecessary costs.

5.7 Concluding Remarks

The purpose of this chapter is to show the usefulness of reliable WTP values in preparing water supply and sanitation projects. Careful design of the contingent market scenarios and all the measures described for ensuring the quality of CV data are paramount in conducting a credible CV study. Once the validity of the study is established through econometric analysis, the study findings can be used to make informed decisions on a number of aspects of project design.

The chapter has shown how to generate useful supplementary information to evaluate households' effective demand for improved service, preference for the institutional provider, the feasibility of spatially based, pro-poor service delivery, affordability by the poor, and acceptability of the improved service under scenarios of different connection charges.

The chapter has also illustrated the use of supplementary information generated through CV studies for analyzing different tariff and subsidy options to design appropriate pro-poor services. A variety of uses of CV data is feasible depending on the specific objectives of a study. The key, however, is to generate a reliable set of data following the quality control measures described in this chapter and Chapter 4.

A CV study generally values a composite commodity by fixing the attribute levels of the service. Conjoint analysis allows valuation of unbundled service attributes separately. This chapter also shows that conjoint analysis can provide supplementary information of policy relevance for designing water supply projects.

APPENDIX 5.1

Closed-Ended Elicitation Questions Used in the Study²¹

As you know, the piped water supply system in your area has some problems. Many households do not have private water connections. A large proportion of the water that could be supplied to people in your area is lost before it reaches people's homes because the water pipes are old, many leak badly, and require frequent repairs. In many places, the pressure in the water distribution network is often low. Many people spend time and money in bringing water from outside and/or invest in wells (hand pumps, tube wells, and dug wells) for storage in their homes. Low pressure can cause groundwater to leak into the pipes, which, combined with inadequate wastewater collection, can contaminate the piped water supply, causing health risks. Sometimes, meters do not function properly, and households with essentially the same water service may receive quite different water bills. Some people in your area incur the expense of boiling and treating their water before they drink it. Unless something is done, the water supply situation in your area is likely to get worse. This is because the population is increasing, and the physical condition of the water system continues to deteriorate. It is possible to improve the water supply condition in your area through public sector reforms, private sector participation, or small scale community initiatives.

Suppose that this new provider is successful in (i) stopping leakage from the system, (ii) providing efficient repair and customer support service, (iii) maintaining and installing new meters so that bills are fair, and (iv) generally, improving the overall performance of the system. However, any improvement to the water supply system will cost money and the provider would expect to be paid for the investment it put into the system, presumably through higher monthly bills. I want you to suppose that it was possible for the improved system to provide customers with a level of service with the following features: (*Enumerator: Show respondent Card*)

²¹ The examples shown in this Appendix are from the authors' Sri Lankan and Nepalese studies. The conversational style of presentation has been preserved. The questionnaires used in these studies are too long to be presented in this chapter; therefore, only selected, important sections are presented. Full questionnaires are available from the authors upon request.

- (1) 24-hour service with good pressure, 7 days a week
- (2) Prompt repair and efficient customer service
- (3) Water that is safe to drink from the tap
- (4) Meters that would function accurately and be read properly

Q.a. Now, I want to ask you a series of questions about how much such improved water service would be worth to you. Let me start by determining whether you have a connection in your house or yard for the exclusive use of your household members.

- (1) Yes, I have such a connection. (GO TO A5.1.1)
- (2) No, I do not have such a connection.
(Enumerator: This category includes public taps, tubewells, borewells, purchase from vendors and tankers, etc.)

Q.b. What is the main reason for your not having connected to the network?

- (1) Cost of connection is too high.
- (2) Monthly bill is too high.
- (3) My application is still pending.
- (4) My house is too far from the network.
- (5) I am satisfied with my current water sources.
- (6) Other (please specify): _____
(GO TO A5.1.2)

A5.1.1 Households with Connection

One can consider several improvements to the water supply service. Suppose all households receive 24-hour service, water that is safe to drink from the tap, accurate billing of the water they receive, and reliable and responsive customer support. But people would have to pay higher water bills. Suppose a private water company provides this service. Such a company will have different investment options, operational autonomy, flexibility in pricing to recover costs, and oversight from a regulatory authority (e.g., to check overcharging). It would expect to raise revenues to cover the cost of improvements. Some people say they would stay connected to the improved water supply system because they really want the improved service and they can afford the higher water bill.

Other people say they would disconnect because they are not really bothered very much by low water pressure, and they cannot afford the higher water bill. There are no right-or-wrong answers. We really want to know what you think.

Q.1. Now, I want you to assume that the improved water service would entitle a typical household like yours to about 500 liters per day. This would cost your household (100/200/300/400/500/600/800/1000) Rupees per month. What do you think your household would do? (*Enumerator: Read choices 1 and 2, not the third*)

- (1) Stay connected and pay the higher water bill
- (2) Disconnect and find water elsewhere
- (3) Don't know

(END OF THE SURVEY)

Q.2. How sure are you of your decision?

- (1) Totally sure
- (2) Somewhat sure
- (3) Equally sure or unsure
- (4) Somewhat unsure
- (5) Totally unsure

(*Enumerator: For those who chose to stay connected, GO TO QUESTION 3; for those who chose disconnected, GO TO QUESTION 4*)

Q.3. Could you explain to me your main reasons for staying connected to the network? (*Enumerator: Allow them to answer on their own. If no answer, then prompt with the following*)

- (1) I really want/need the improved water service.
- (2) The increased water bill is not too high.
- (3) I am worried about the health risks of the existing water service.
- (4) I like the idea of having a private company involved in managing the water supply system.
- (5) Other (please specify): _____
- (6) Don't know/not sure

(END OF SURVEY)

- Q.4. Could you explain to me your main reasons for disconnecting from the network?
- (1) I do not really want/need the improved water service
 - (2) The increased water bill is too high; I cannot afford it
 - (3) I am not worried about the health risks of the existing water service
 - (4) I do not want a private company involved in water supply system
 - (5) Other (please specify): _____
 - (6) Don't know/not sure
- Q.5. If you disconnected from the water system, where do you think your household would obtain your water supplies?
- (1) Public taps
 - (2) Private well
 - (3) Neighbors
 - (4) Community schemes
 - (5) Vendors and tankers
 - (6) Other (please specify): _____
 - (7) Don't know/not sure

A5.1.2 Households without Connection

One can consider several improvements to the water supply service. Suppose all households receive 24-hour service, water that was safe to drink from the tap, accurate billing of the water they received and reliable and responsive customer support. But people would have to pay higher water bills. Suppose a private water company provides this service. Such a company will have different investment options, operational autonomy, flexibility in pricing to recover costs, and oversight from a regulatory authority (e.g., to check overcharging). It would expect to raise revenues to cover the cost of improvements. Some people say they would stay connected to the improved water supply system because they really want the improved service and they can afford the higher water bill. Other people say they would disconnect because they are not really bothered very much by low water pressure, and they cannot afford the higher water bill. There are no right-or-wrong answers. We really want to know what you think.

Q.1. Now, I want you to assume that the improved water service would entitle a typical household like yours to about 500 liters per day. This would cost your household (100/200/300/400/500/600/800/1000) Rupees per month and one time connection charges of (6000/8000/10000/12000) Rupees. What do you think your household would do? (*Enumerator: Read choices 1 and 2, not the third*)

- (1) Get a private connection.
 - (2) Continue as is.
 - (3) Don't know
- (END OF SURVEY)

Q.2. How sure are you of your decision?

- (1) Totally sure
- (2) Somewhat sure
- (3) Equally sure or unsure
- (4) Somewhat unsure
- (5) Totally unsure

(Enumerator: For those who chose "stay connected," GO TO QUESTION 3; for those who chose "disconnected," GO TO QUESTION 4).

Q.3. Could you explain to me your main reasons for connecting to the network?

(Enumerator: Allow them to answer on their own. If no answer, then prompt with the following)

- (1) I really want/need the improved water service.
 - (0) The increased water bill is not too high.
 - (3) I am worried about the health risks of the existing water service.
 - (4) I like the idea of having a private company involved in managing the water supply system.
 - (5) Other (please specify): _____
 - (6) Don't know/not sure
- (END OF SURVEY)

Q.4. Could you explain to me your main reasons for not connecting to the network?

- (1) I do not really want/need the improved water service.
 - (2) The increased water bill is too high; I cannot afford it.
 - (3) I am not worried about the health risks of the existing water service.
 - (4) I do not want a private company involved in water supply system.
 - (5) Other (please specify): _____
 - (6) Don't know/not sure
- Q.5. Would you change your mind and connect to the network if it was possible to modify this plan and allow you to pay off the connection charge in monthly installments collected along with your monthly bill for consumption?
- (1) Yes
 - (2) No
- Q.6. If you did not connect to the water network, where do you think your household would obtain your water supplies?
- (1) Public taps
 - (2) Private well
 - (3) Neighbors
 - (4) Community schemes
 - (5) Browsers, vendors and tankers
 - (6) Other (please specify): _____
 - (7) Don't know/not sure

APPENDIX 5.2

Step-By-Step Procedure for Estimating Mean Willingness to Pay and Example of Policy Simulations

A5.2.1 Estimation of Mean Willingness to Pay (WTP)

Step 1: Run a simple Probit regression in any statistical software of your choice (e.g., SPSS, SAS, STATA, LIMDEP, SHAZAM, etc.). We use the results presented in Table 5.3 for illustration purposes.

Variable	Mean (X)	Coefficient (Y)	X*Y
Regression constant		1.119 **	1.119
Monthly consumption charge (Rs.)	487	-0.002 **	-
One-time connection cost (Rs.)	5,534	-0.00003 **	-
Monthly per capita consumption (Rs.)	6,044	0.00003 **	0.181
Household receives remittance (1 = yes; 0 = no)	0.10	0.276 **	0.028
Household is a Samurdhi recipient (1 = yes; 0 = no)	0.19	-0.245 **	-0.047
Household head is employed in private sector (1 = yes; 0 = no)	0.41	0.213 **	0.087
Distance to road (kilometers)	0.32	0.112	0.036
Household resides in Greater Negombo (1 = yes; 0 = Kalutara or Galle)	0.45	-0.484 **	-0.218
Household resides in Kalutara (1 = yes; 0 = Greater Negombo or Galle)	0.23	-0.326 **	-0.075
% of households with access to private wells in Greater Negombo	0.79	-0.329 **	-0.260
% of households that consider water quality of their alternative sources as excellent or good in Greater Negombo	0.59	-0.312 **	-0.184

continued on next page.

Table A5.2.1 continued.

Table A5.2.1 Probit Regression Results			
Variable	Mean (X)	Coefficient (Y)	X*Y
Household believes that there is a water contamination problem (1 = yes; 0 = no)	0.10	0.248 **	0.025
Household thinks government should give connection subsidy to low-income households for improved water supply services (1 = yes; 0 = no)	0.30	0.025	0.008
Household is particularly conscious of institutional issues (1 = yes; 0 = no)	0.01	0.570 **	0.006
Private sector will provide improved service (1 = yes; 0 = public sector will provide)	0.55	-0.116 *	-0.064
Household is particularly conscious of health issues (1 = yes; 0 = no)	0.02	0.648 **	0.013
Household has experienced a case of morbidity event (1 = yes; 0 = no)	0.02	0.649 **	0.013
Household is Tamil (1 = yes; 0 = no)	0.03	-0.475 **	-0.014
Household owns the house (1 = yes; 0 = no)	0.94	-0.322 **	-0.303
Education of household head (years)	9	0.021 *	0.189

Step 1: Estimate a combined intercept by multiplying the regression coefficients by the corresponding mean values of the corresponding variables. This calculation should exclude the two bid variables as shown in the fourth column of the table above.

Step 2: Sum up the products to get the combined intercept. You will get 0.540 as your coefficient.

Step 3: To calculate the mean WTP, divide the coefficient on ‘cons’ (0.540) by the coefficient on ‘bid’ (-0.002) and multiply by -1. You should get a value of Rs. 270 which is the mean WTP for the overall sample.

A5.2.2 Connection Prediction

Step 1: Generate summary statistics and run the Probit regression in any statistical software of your choice (e.g., SPSS, SAS, STATA, LIMDEP, etc.). The sample results below are generated using STATA and fabricated for illustration purposes only.

(a) summary statistics

. summarize wbid wconnfee private head_edu2 owner poor1 roaddist

Variable	Obs	Mean	Std. Dev.	Min	Max
wbid	1,818	487.35	284.75	100	1,000
wconnfee	1,818	5,533.55	4,734.24	0	12,000
private	1,818	.55	.49	0	1
head_edu2	1,818	8.93	3.06	0	20
owner	1,818	9,372,937	.24	0	1
poor	1,818	.20	.40	0	1
roaddist	1,818	.32	.46	0	2.5

(b) regression results

. Probit wat_cv wbid wconnfee private head_edu2 owner poor1 roaddist

. Probit regression Number of obs = 1,735
 LR chi2(7) = 295.66
 Prob > chi2 = 0.0000

Log likelihood = -988.91978 Pseudo R2 = 0.1300

wat_cv	Coef.	Std. Err.	Z	P> z	[95% Conf. Interval]	
wbid	-.001559	.000124	-12.57	0.000	-.001802	-.001316
wconnfee	-.0000536	7.16e-06	-7.49	0.000	-.0000677	-.0000396
private	-.1290851	.0659277	-1.96	0.050	-.2583011	-.0001308
head_edu2	.0227382	.0115323	1.97	0.049	.0001352	-.0453412
owner	-.2866908	.1379495	-2.08	0.038	-.5570669	-.0163148
poor	-.3165037	.0916355	-3.45	0.001	-.496106	-.1369015
roaddist	.0494128	.072121	0.69	0.493	-.0919418	-.1907674
_cons	.8342576	.193991	4.30	0.000	.4540421	-1.214473

where,

- wat_cv = Household responses to the CV question:
1 = households want the improved service;
0 = households do not want the improved service)
- wbid = Proposed monthly consumption charge (Rs.)
- wconnfee = Proposed one-time connection fee (Rs.)
- private = Private sector will provide improved service:
1 = yes;
0 = public sector will provide
- head_edu2 = Education of household head (years)
- owner = Household owns the house (1 = yes; 0 = no)
- poor = Household is poor (1 = yes; 0 = no)
- roaddist = Distance to main road (kilometers)
- _cons = Regression constant

Step 2: Input mean values and coefficients of variables in the regression in an Excel worksheet as follows. Enter variable descriptions in the second column, mean values in the third, and regression coefficients in the fourth.

Table A5.2.2

Item	Variable Description	Mean	Coefficient
1	Regression constant	1	0.834
2	Proposed monthly consumption charge (Rs.)	487	-0.002
3	Proposed one-time connection fee (Rs.)	5,534	-0.00005
4	Private sector will provide improved service (1 = yes; 0 = public sector will provide)	0.55	-0.129
5	Education of household head (years)	8.94	0.023
6	Household owns the house (1 = yes; 0 = no)	0.94	-0.287
7	Household is poor (1 = yes; 0 = no)	0.20	-
8	Distance to main road (kilometers)	0.32	0.049

Step 3: In the fifth column, enter the policy scenario you would like to evaluate and simulate. Say you would like to predict what percent of the poor, unconnected households would have a household connection if the public sector provides the improved service, and connection fee for unconnected households is Rs.9,000. In

other words, you will key in 9,000 for item #3, 0 for item #4, and 1 for item #7. For the rest, just enter the same values shown in the third column. Note that if we want to do this for the entire sample (not for the poor), we should use the mean (0.20) for item 7.

Table A5.2.3

Item	Variable description	Mean	Coefficient	Policy scenario
1	Regression constant	1	0.834	1
2	Proposed monthly consumption charge (Rs.)	487	-0.002	487
3	Proposed one time connection fee (Rs.)	5,534	-0.00005	9,000
4	Private sector will provide improved service (1 = yes; 0 = public sector will provide)	0.55	-0.129	0
5	Education of household head (years)	8.94	0.023	8.94
6	Household owns the house (1 = yes; 0 = no)	0.94	-0.287	0.94
7	Household is poor (1 = yes; 0 = no)	0.20	-0.317	1
8	Distance to main road (kilometers)	0.32	0.049	0.32

Step 4: In the sixth column, simply multiply the values in columns 4 and 5 for each variable.

Table A5.2.4

Item	Variable description	Mean	Coefficient	Policy scenario	Coefficient * policy scenario
1	Regression constant	1	0.834	1	0.834
2	Proposed monthly consumption charge (Rs.)	487	-0.002	487	-0.759
3	Proposed one time connection fee (Rs.)	5,534	-0.00005	9,000	-0.482
4	Private sector will provide improved service (1 = yes; 0 = public sector will provide)	0.55	-0.129	0	0.000
5	Education of household head (years)	8.94	0.023	8.94	0.203

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Table A5.2.4 continued.

Table A5.2.4					
Item	Variable description	Mean	Coefficient	Policy scenario	Coefficient * policy scenario
6	Household owns the house (1 = yes; 0 = no)	0.94	-0.287	0.94	-0.269
7	Household is poor (1 = yes; 0 = no)	0.20	-0.317	1	-0.317
8	Distance to main road (kilometers)	0.32	0.049	0.32	0.016

Step 5: Sum up the values in the sixth column. You should obtain a value of -0.774 .

Step 6: Apply a function called “NORMSDIST” in Excel to the value obtained in Step 5. You should get a value of 22% which is the predicted connection rate for this particular policy scenario.

APPENDIX 5.3 Subsidy Simulations

In developing economies, privatizing water supply service has drawn much debate due to anticipated higher charges, and the impact of such charges on the poor. To assess affordability for the poor, the findings of a CV study can be further used to analyze water consumption tariffs and subsidies.

The CV study in Nepal by Pattanayak and Yang (2002) conducted simulation exercises using four different scenarios: (i) marginal modification to existing tariff, (ii) tariff for full cost recovery, (iii) full cost recovery with 100% metering, and (iv) service network expansion. These scenarios were evaluated under four alternatives: uniform tariff, modified tariff, geographic targeting, and individual targeting. The combination of scenarios and alternatives generated a large number of different outcomes.

Following are the steps in undertaking subsidy simulations.

Step 1: Estimate a regression function for quantity of water consumed by households. Estimation of this equation provides a tool for different purposes. Here, this function is used to predict water consumption for those households where meters were not available or malfunctioning. The analyst can estimate water consumption, Q , for these households by substituting appropriate values of independent variables.²² The results will be used in Step 4.

$$Q = \beta_0 + \beta_s * S + \beta_w * W + \beta_o * O + \beta_d * D + \varepsilon_1$$

where:

Q is the total monthly consumption of water,
 S is a vector of socioeconomic factors,
 W is a vector of current WSS type,
 O is a vector of opinions and attitudes,
 D is a vector of demographic characteristics,
 ε_1 is the regression error, and
 β_s are regression coefficients to be estimated.

Step 2: Collect supply-side information from the water utilities: average cost of water provision (C , Rupees/m³) and existing tariff structure.

Step 3: Input household level data from the survey into an Excel worksheet. Make sure monthly water expenditure and monthly water consumption are available for each household.

Step 4: Calculate financial subsidies for each household using Equation 1.

$$S_i = Q_i * C - UC_{ui} \quad (1)$$

²² See Pattanayak and Yang (2002) for an example of an OLS model for water consumption in the Kathmandu Valley of Nepal. They found that water consumption was positively correlated with income, family size, total number of water sources accessible, storage capacity, perception regarding regularity of network supply, and exclusive reliance on private water sources. This model was used to impute water consumption for households without water meters.

where S_i is the subsidy for the i th household,
 Q_i is water consumption from the water utilities by the
 i th household, and
 UC_{ui} is the utility charge to each household i .

If a household is not connected to the water network, it will receive zero subsidy. Note that Step 1 provides data on Q_i for unmetered households or households with malfunctioning meters.

Step 5: Calculate errors of exclusion and inclusion using Equations 2 and 3.

“Error of Exclusion” is defined as the following ratio:

$$\frac{\sum \text{Number of Poor Households Not Subsidized}}{\sum \text{Total Number of Poor Households}} \quad (2)$$

“Error of Inclusion” is defined as the following ratio:

$$\frac{\sum \text{Number of Non-Poor Households Receiving Subsidies}}{\sum \text{Total Number of Households Receiving Subsidies}} \quad (3)$$

Step 6: To simulate different policy scenarios, you can either manipulate the existing parameters (e.g., tariff structure) or create new parameters that are of interest (e.g., targeting poor communities or poor households). Then repeat Steps 1 to 5.

Four policy alternatives (uniform tariff, modified tariff, geographic targeting, and individual targeting) were considered when the methodology was applied in Nepal. Note these scenarios alter the C_{ui} **variable in Equation 1**. The existing tariff system was an increasing block system. The proposed uniform tariff would change it to a uniform linear tariff per cubic meter and the modified system would reduce the lifeline block to 7 cubic meters per month instead of the existing 10 cubic meters.²³ Geographic targeting included neighborhoods with more than

²³ This is based on the survey findings that the mean consumption of poor people is about 7 cubic meters.

60% of poor people. Individual targeting would only provide subsidy for the identified poor households. In the original study, these four policy alternatives were analyzed under four different scenarios.

Table A5.3.1 presents the results of one scenario: full cost recovery. The distributional incidence of these subsidies is summarized by estimating quasi-Gini coefficients and errors of inclusion and exclusion parameters. The results show that individual targeting is a better option in terms of effectiveness of providing a subsidy. However, this option provides the lowest revenue to the utilities and the transaction cost of its implementation is also high. The analysis provides a comprehensive picture of the pros and cons of different subsidy scenarios enabling the project team to design an effective subsidy scheme.

Table A5.3.1 Comparison of Alternative Subsidy Schemes in Kathmandu, Nepal

Policy Alternative	Number of households receiving subsidies	Quasi-Gini	Poor get % subsidy	Error of exclusion (%)	Error of inclusion (%)	Total revenue (NPR)
Uniform tariff	330	0.429	12	89	81	642,699
Modified tariff	625	0.288	19	75	76	537,465
Geographic targeting	557	0.167	29	77	75	577,913
Individual targeting	514	0.043	36	73	68	499,796

NPR = Nepalese Rupee.

Note: This set of simulations considers charging households the full cost of water unless they are targeted for subsidies.

Source: Pattanayak and Yang (2002).

Furthermore, the data from the survey, combined with the results generated from the steps above, can be used to undertake additional analysis of the impact of subsidies on different income groups. Table A5.3.2 presents the subsidy incidence for the 'individual targeting' alternative (under the scenario of full cost recovery with 100% metering).

Table A5.3.2 Subsidy Incidence by Income Deciles in Kathmandu, Nepal

Decile	Income	Number of households	Number of new connections	% of total subsidies	Subsidies as % income
1	< 4,500	166	99	19	7
2	4,501–6,000	197	109	21	4
3	6,001–7,000	127	60	12	3
4	7,001–8,500	115	45	9	2
5	8,501–10,000	172	46	9	1
6	10,001–12,000	137	42	8	1
7	12,001–15,000	154	36	7	1
8	15,001–20,000	150	34	7	1
9	20,001–30,000	143	21	4	0
10	> 30,001	139	26	5	0
Population		1,500	518	100	1

Source: Pattanayak and Yang (2002).

6. Economic Analysis of Integrated Services Projects

6.1 Introduction

One of the main challenges in undertaking economic analyses of integrated urban development projects is their multisectoral nature. Such projects often include water supply, wastewater treatment, solid waste management, transport and environmental improvements and, in some cases, housing and household heating. Such an analysis requires more effort and greater resources than projects that cover only a single sector. An urban transport component, for example, may require all the steps and the same amount of effort needed for a stand-alone highway project. The challenge is therefore to apply acceptable methods to the economic analysis given limited time and resources while maintaining rigor and quality.

One approach to meeting this challenge is through benefit transfer, which uses data from a pre-existing analysis of the sector or from an analysis undertaken for a similar project in a different location. This chapter describes and illustrates this method.

The Asian Development Bank's (ADB) *Guidelines for the Economic Analysis of Projects* (ADB 1997) distinguishes between incremental and non-incremental outputs in view of the different basis of their valuation. As a general rule, non-incremental benefits can be valued at resource cost savings, while incremental benefits can be assessed through willingness to pay (WTP). When demand functions or related market information are available, this general approach can be applied to value the benefits of urban services.

In developing countries however, where econometrically estimated demand functions for urban services are rarely available, contingent valuation (CV) studies are very useful for estimating the benefits

of urban services such as water supply, solid waste collection, and sanitation. WTP for these services is determined by service attributes such as quantity, quality, reliability, and customer service quality, as well as institutional attributes (private vs. public provision). The distinction between incremental and non-incremental benefits becomes irrelevant under the CV method because the improved service can be considered a new commodity and WTP pertains to both incremental and non-incremental benefits.

This chapter has three main sections. Section 6.2 outlines the concepts and approaches to benefit estimation for different types of urban services. It also provides an example of hedonic pricing, related to urban improvements that raise property values. Section 6.3 explains the benefit transfer method. Section 6.4 then applies various benefit estimation approaches to an ADB urban services project in Hebei Province in the People's Republic of China (PRC), which satisfactorily illustrates the benefit transfer method.

6.2 Approaches to Benefit Estimation

6.2.1 Data Availability and Choice of Methodology

Economic analyses of urban development projects require careful assessment of the availability of data and suitability of methodologies at the very early stages of project preparation. Some components, such as water supply and sanitation (WSS), solid waste management (SWM), and household heating, can be analyzed using different methods. Early selection of methods allows the analyst to allocate resources efficiently and avoid discovering data deficiencies in the middle of project preparatory studies.

For example, if the CV method is chosen for WSS or SWM components, additional resources need to be allocated to conduct a field survey. If revealed preference methods are chosen to estimate the benefits of a WSS component, such as time and coping cost savings or hedonic pricing methods, data availability should be verified at the design stage of the analysis.

A useful first step in screening the methods is to separate the components that can be subjected to cost-benefit analysis (CBA) from those that require cost-effectiveness analysis (CEA) or least-cost analysis (LCA). CBA is generally preferred, but when quantification of benefits is difficult, CEA is used as a compromise solution.

6.2.2 Revealed Preference vs. Stated Preference

The various approaches for estimating benefits can be categorized into either revealed preference methods or stated preference methods.

Revealed preference methods use market information and are based on the actual behavior of individuals participating in the market exchange process. Demand functions, supply functions, and related competitive market prices constitute the core of the revealed preference information that helps in valuing benefits. Revealed preference methods are divided into two categories: direct observed methods and indirect observed methods.

Revealed preference methods	Stated preference methods
Direct Demand, supply, price Human capital Productivity change Cost-of-illness Statistical value of life Defensive expenditures	Contingent valuation (composite commodity) Choice experiments (attributes of a commodity)
Indirect Travel cost Hedonic pricing or property value model Hedonic travel cost Wage differential	

Direct observed methods use the demand, supply, or price information of the commodities directly related to the project. Market prices, human capital, cost-of-illness, statistical value of life, and defensive expenditure methods are the direct revealed preference methods generally used to estimate the benefits of health improvements or accident costs. The

productivity change method values lost production using market prices to estimate the benefits of an environmental change. Crop yield change due to soil erosion is an example. All these methods using market information to value benefits are considered revealed preference methods.

Indirect revealed preference methods still use market information, but of a related commodity to value benefits of an improvement in the environment or natural resource availability. The travel cost method estimates the demand for and benefits from recreation by analyzing the actual cost incurred in traveling to a recreational site. The hedonic pricing method estimates the benefits from an urban amenity improvement using the change in property prices. The hedonic travel cost method combines the travel costs and site quality to estimate the benefits of recreational site quality improvements. The wage differential method allows estimation of the benefits of reducing risks in the workplace, on the premise that people may be willing to accept risky occupations, such as in hazardous chemical or cement factories, provided that they are adequately compensated.

Stated preference methods use hypothetical behavior stated in surveys in response to a hypothetical question. CV and choice experiments are two basic types of stated preference methods. CV uses the survey method to elicit the benefits of a composite commodity, such as water supply, whereas choice experiments (also known as conjoint analysis) use a similar method to value different attributes of a commodity separately (such as reliability, quality of water). Chapter 4 illustrates the application of both methods.

Economists generally prefer revealed preference methods in valuing benefits, provided they are derived from well-functioning markets, because revealed preference data are more reliable and represent the actual behavior of market participants. However, such data is often not available for the benefit valuation of urban services in developing countries. Stated preference methods provide a feasible alternative, but eliciting consumer preferences through surveys is not easy and large errors can occur in poorly conducted stated preference surveys. Chapter 4 describes good practices to minimize such errors.

6.2.3 Benefit Estimation for Various Urban Services

Table 6.1 provides a summary of the applicable methods to estimate benefits and suitable analytical tools for appraising project components.

Transport. The benefits from transport projects can be estimated using a variety of methods, as described in Chapter 6. However, the effort required to analyze a transport component of an urban project is as much as that of a larger, stand-alone transport project. The analyst should be mindful of the time and resources that should be allocated to this component and try to make the best use of secondary sources of data on traffic counts, value of working and non-working time, conversion factors, and so on, when preparing the analysis.

Household heating. Estimating the benefits of household heating and undertaking cost-benefit analysis (CBA) are feasible under most circumstances. The benefits can be estimated using a number of approaches. Among the revealed preference methods, resource cost savings can be applied because the required data can be easily generated. As central heating facilities are made available, existing systems that use coal or firewood will be replaced. Information on the market values of firewood or coal, together with appropriate shadow price coefficients, can be used to estimate resource cost savings. One issue that needs to be verified in applying this method is whether there will be incremental benefits, that is, whether households will use additional heating when cheaper and cleaner energy sources are made available to them. Under most circumstances, given the basic essential nature of household heating, it can be safely assumed that there is no incremental increase in heating. If there is evidence of an incremental increase in heating due to the availability of cheap and better quality heating, households' WTP should be estimated and added to the benefit stream.

Another benefit that can be added to the benefit stream is the avoided health costs of indoor air pollution created by the project's replacement of dirty energy sources. Whenever the resource cost savings method is not feasible, a CV survey may be considered for estimating the benefits of heating. However, there is limited knowledge and actual experience to date on the successful use of this method to value the benefits of household heating.

Table 6.1 Methods for Estimating the Economic Benefits of Urban Service Improvements

Component	Methodology	
	Methods of benefit estimation	Analytical tools
Transport	<ul style="list-style-type: none"> • Cost savings (vehicle operating costs, time savings) • Defensive expenditure on environmental and accident costs • Cost-of-illness, statistical value of life, and human capital approach (accident cost savings) • Contingent valuation (for new mode of transport) • Avoided costs (maintenance, accident costs, environmental) 	Cost–benefit analysis
Household heating	<ul style="list-style-type: none"> • Resource cost savings • Avoided costs (environmental) • Contingent valuation 	Cost–benefit analysis
River improvement	<ul style="list-style-type: none"> • Contingent valuation • Hedonic pricing • Cost-of-illness, statistical value of life, and human capital approach (health benefits) 	Least-cost analysis Cost–benefit analysis
Wastewater treatment	<ul style="list-style-type: none"> • Contingent valuation • Cost-of-illness, statistical value of life, and human capital approach (health benefits) • Hedonic pricing 	Cost–benefit analysis
Solid waste management	<ul style="list-style-type: none"> • Contingent valuation • Cost-of-illness, statistical value of life, and human capital approach (health benefits) • Hedonic pricing 	Cost–benefit analysis
Water supply	<ul style="list-style-type: none"> • Resource cost savings (alternative sources, water supply system costs, time savings) • Cost-of-illness, statistical value of life, and human capital approach (health benefits) • Contingent valuation • Hedonic pricing 	Cost–benefit analysis
Public toilets	<ul style="list-style-type: none"> • Contingent valuation 	Least-cost analysis

Source: Economic Analysis and Operations Support Division, Economics and Research Department, ADB.

River improvement. Although infrequent, some urban projects have river improvement components, such as the cleaning of polluted and silted rivers, civil works to straighten and stabilize river banks, and environmental improvements such as tree planting, and walking and jogging path construction. These are usually linked with SWM and wastewater treatment and disposal. Avoided health costs can be considered benefits of river improvements, but data may not be available. CV seems, potentially, to be the applicable method for estimating the benefits of river improvements. However, its application for this type of project is not easy because of the difficulty for households to perceive potential private benefits, which are public goods in nature. Also, previous applications of the CV method for this type of environmental improvement in developing countries are few.

Therefore, LCA provides a pragmatic solution in undertaking the economic analysis of river improvements, especially when such components bear a small proportion of project costs. If the river improvement is a stand-alone project or a large component of an urban project, extra effort should be made to estimate the benefits and undertake CBA.

Wastewater treatment. The benefits of wastewater treatment can be estimated using avoided health damages (using cost-of-illness, human capital, or statistical value of life approaches), CV, and sometimes hedonic pricing models. Estimation of mortality and morbidity costs related to sanitation problems requires data on disease and death incidence, without and with the project. Accurate information on disease and death incidence attributable to poor sanitation is generally not available in developing countries. Moreover, predicting the reduction of disease and death incidence with the project is challenging. One way to overcome this difficulty is to survey the study area and a similar area (control area), with proper sanitation as the main difference. The differences in disease incidence and premature deaths in the two areas will provide a proxy for dose-response information. The rigor of this crude method can be significantly improved by developing regression models to accurately estimate the disease and death differences with and without the project, when time and resources permit such detailed analysis.¹

¹ The dependent variable of the regression model is disease or death incidence and should include a set of independent variables that determine deaths and diseases. A dummy variable for the availability of sanitation can be incorporated; the coefficient indicates the reduction in disease/death with the project.

The rest of the required data to estimate morbidity costs—such as medical and other related costs of treatment, cost of averting activities such as boiling water, and so on, and information on wages lost due to sickness—can be generated through a survey. Under most circumstances, the data required under the cost-of-illness and human capital approaches (based on discounted lifetime earnings) are available or can be generated in developing countries. Hence, health benefits estimated using the cost-of-illness, human capital, or statistical value of life approaches will provide a good proxy for the benefits of wastewater treatment.² If any significant coping or averting costs are involved, such costs should be added to the benefits.

In the absence of data, a CV survey can be conducted to estimate health benefits. As a general rule, CBA can be undertaken for wastewater treatment under most circumstances.

Solid waste management. As in wastewater treatment, the benefits of SWM can be estimated as avoided health cost or by using CV methods. SWM projects may involve separation of wastes and composting. If any separated waste is reused, its market value and that of the organic fertilizer generated by waste processing can be added to the benefits. However, when such benefits are used, the analyst should be careful to avoid double counting.

Water supply. The benefits of water supply projects can be estimated using a number of methods, such as resource cost savings (purchase of alternative sources of water or time spent collecting water), health benefits, and, in some cases, hedonic pricing methods (see 6.2.4). The economic benefits of improved water supply can also be estimated using the CV method, as shown in Chapter 5. ADB's *Handbook for the Economic Analysis of Water Supply Projects* (ADB 1999) recommends the use of resource cost savings for estimating non-incremental benefits and WTP for the incremental benefits of a water supply project. If an econometrically estimated demand function for water is available, this approach can be applied to get more accurate estimates of benefits. Such demand functions are, however, rarely available for developing countries. Therefore, the applicability of this method depends on the availability of data, such as the quantity and price of current sources of water that will be replaced by the project and the incremental consumption of water and its economic price.

² The cost-of-illness approach does not include the disutility of being sick and, therefore, only captures part of the benefits of reducing the incidence of sickness.

Estimating incremental consumption is often difficult and the economic price or MWTP cannot be estimated (without a CV study). Using the administratively determined tariff as a proxy for WTP may result in errors. As water is a composite commodity, the hours of supply (reliability), water quality, and customer service quality together, define its value. For households with water connections, WTP depends on service quality improvements. In such cases the CV method, despite the difficulties involved in eliciting benefits through surveys, provides a better way to estimate benefits. The CV method explicitly takes into account the improvements in attributes such as hours of supply, water quality, and customer service quality. A CV study also provides valuable insights on demand and water tariffs. In addition, the benefits estimated through CV can be transferred to other projects.

Public toilets. Estimation of the benefits of public toilet facilities is not easy. While the CV method might be applied, a CV question may confuse respondents because public toilets are generally provided without charge. As discussed in Chapter 4, it is easy for respondents to understand the contingent market when there is a reasonable payment vehicle, such as water bills in the case of water supply. Given this difficulty and the lack of previous applications, the use of the CV method and CBA is not practical for estimating and assessing the benefits of public toilets. In many cases, public toilet components constitute a very small proportion of project costs, and adding only their costs—but not their benefits—in the CBA of the overall project has little impact on the economic internal rate of return (EIRR). Whenever feasible alternative options are available, LCA is encouraged.

6.2.4 Hedonic Pricing

As discussed above, hedonic pricing models, otherwise known as “property value models”, can be used to estimate the benefits of urban infrastructure improvements. If certain assumptions on the functioning of markets hold, this method provides the theoretically correct estimate of the benefits of urban improvements, and its application is therefore encouraged wherever feasible. Property value models require the estimation of a regression equation, taking the property price (land or house) as the dependent variable and a set of variables that determine

the property value as independent variables. The availability of water supply, sanitation, or solid waste management can enter as amenities in the regression equation and their coefficients indicate the benefits of urban improvements (see Box 6.1 for an example).³

Box 6.1 Hedonic Pricing Example

Environmental attributes such as air and water quality and urban amenities such as water supply, sanitation, and solid waste management, affect the value of real estate property. The equilibrium market price of a property should therefore reflect any change in those attributes or amenities. Based on this rationale, the following regression equation can be specified:

$$P_i = f(Q_i, S_i, N_i)$$

where P_i is the price of a property, Q_i is a vector of environmental amenities of the property, S_i is a vector of characteristics of the property, and N_i is a vector of neighborhood characteristics.

For a house, Q includes air quality, noise pollution, and other attributes in the vicinity of the property; S usually includes size, number of bedrooms, number of bathrooms, age, and type of construction; N includes the quality of local schools, accessibility to parks, crime rate, distance to the city center, availability of public utilities such as water supply, electricity, and availability of public transport. A regression of the property price with the above independent variables forms the hedonic pricing model. The coefficient on the amenity variable indicates the benefit of a higher property value.

In the application of the hedonic pricing model, the following assumptions are made:

- People are aware of the level of the environmental or urban amenity attribute that they are interested in when they purchase the property.
- People's preferences are separable in relation to housing characteristics and that environmental amenities are specific to property locations.
- The hedonic price equation includes the variables people really value in purchasing the property.
- Attributes of the property are continuous and all varieties that interest the consumers are available.
- There is a well-functioning market for the property, that is, the market adjusts immediately to changes in the quality attributes being considered, including the urban amenities.

To illustrate an application of the hedonic pricing model, actual property sales price data and the following housing characteristics were included in the model.

Total floor area (TSQF), ft²
 Number of bedrooms (BEDRMS)
 Number of bathrooms (BATHRMS)
 Age of the house (AGE), years

continued on next page.

³ See Freeman III (1993) for theory and Gunatilake (2003) for an application of the hedonic pricing model.

Box 6.1 continued.

Year of sale (related to dummy variables D86, D87, D88, D89)
 Availability of garage (GARAGE) (dummy, available = 1, otherwise = 0)
 Availability of view (VIEW) (dummy, available = 1, otherwise = 0)
 Availability of fire place (FIREPLAC) (dummy, available = 1, otherwise = 0)
 Availability of porch (PORCH) (dummy, available = 1, otherwise = 0)
 Distance to the waterfront (DISTANCE), meters

Variable	Coefficient	Standard error	t-ratio	P[T >t]
Constant	-16,241.901	39,112.211	-0.415	0.679
TSQF	36.631	9.874	3.710**	0.0004
BEDRMS	25,574.191	7,320.941	3.493**	0.0008
BATHRMS	42,882.055	17,836.214	2.404**	0.018
AGE	-161.286	480.763	-0.335	0.738
GARAGE	11,386.759	20,045.550	0.568	0.572
VIEW	49,693.261	25,202.916	1.972**	0.0519
FIREPLAC	15,112.140	6,015.769	2.512**	0.0139
PORCH	-4,651.228	11,943.199	-0.389	0.698
DISTANCE	-15.321	4.819	-3.179**	0.0021
SEWER	15,011.311	6,082.211	2.467**	0.014
D86	24,062.606	17,273.399	1.393	0.167
D87	43,775.210	17,453.136	2.508**	0.014
D88	39,466.647	17,437.323	2.263**	0.026
D89	44,721.681	16,852.453	2.654**	0.010

Data were collected for 5 years of property sales starting from 1985. Four dummy variables (D86 to D89) were incorporated to correct for inflation, taking 1985 as the reference year. The results are self-explanatory. For example, a house with an extra bedroom will have a price that is \$25,574 higher than a house without that extra room. Similarly, a house with a fireplace will have a sale price that is \$15,112 higher. Three important amenity variables are in the model: the view, distance to the waterfront, and access to the central sewer system. The benefits of a view are estimated at \$49,693, while the value of a house will be \$15 lower for every meter it is located further from the waterfront. The benefit of having a central sewer system is valued at \$15,011. The value of having access to a central sewer system can be readily used in assessing the economic viability of a sanitation project. Land prices can be analyzed in the same way. See Leggett and Bockstael (2000) for a study of the effect of water quality on residential land prices.

Note: The results of the original study were modified for illustration purposes.
 Source: Gunatilake (2003).

Despite its theoretical appeal, the use of the hedonic pricing method is constrained by two factors: lack of data and market imperfections. The method properly captures the benefits of urban infrastructure improvements only when there are undistorted property markets. Undistorted and well-functioning property markets, particularly land markets, are very rare in developing countries. Therefore, application of this method is difficult in project preparatory studies. Sometimes, without proper hedonic pricing model estimation, assumed land value increases due to urban service improvements are used as proxies for the benefits. This practice is discouraged as it is theoretically incorrect (it does not separate the impact of other factors on property prices) and often overestimates the benefits of a specific project improvement.

6.2.5 Benefit Transfer Method

As noted above, the CV method can be used to estimate the benefits of many components of urban projects. Undertaking CV studies for every project or subproject, however, is not easy as it requires specific skills, time, and resources, as explained in Chapters 4 and 5. This section shows how the analyst can resolve this problem by using the benefit function transfer method, which is used to estimate benefits by adapting existing benefit values or functions from one context to another, e.g., location or time. Given the budget and time limitations analysts face, the interest in using project benefits estimated for one setting (study site) to calculate benefits (or direct use of benefits) in another setting (policy site) has been growing (Krupnick 1993). The benefit transfer method can be very useful in multisector projects such as urban projects.

In general, primary data collection on a site-by-site basis to estimate benefits can be expensive and time-consuming. For certain purposes, such as project economic analysis, analysts need to obtain benefit estimates in a timely manner. Benefit transfer methods provide a solution for the difficulties analysts face in estimating benefits for a number of sectors in urban projects. In particular, the use of benefit transfer methods in sector projects allows the transfer of benefits estimated for the initial set of core subprojects to follow-up subprojects. The same is applicable for similar projects under the multitranche financing facility (MFF). Here, the benefits estimated for a site are used to estimate the benefits in a

very similar site and the potential for error can be minimized. However, many studies have pointed out that inappropriate application of the benefit transfer method can lead to large errors and eventually result in incorrect policy recommendations (see Table 6.2).⁴ Therefore, selective application of benefit transfer methods with the required analytical rigor is of paramount importance. In this chapter, we use the benefit transfer method selectively on water supply, wastewater treatment, and solid waste management.

There are two basic methods of benefit transfer: transfer of point estimates of benefit and transfer of the entire benefit function. In the first approach, the point estimates of benefit from the study site are directly transferred to the policy site. This transfer can be with or without adjustments for the income differences in the study and policy sites. A widely used formula for adjusting the benefits for income differences is:

$$WTP_p = WTP_s (Y_p/Y_s)^e \quad (1)$$

where WTP_p is the benefits at the policy site, WTP_s is the benefits at the study site, Y_p is the per capita income at the policy site, Y_s is the per capita income at the study site, and e is the income elasticity of WTP.

The use of the above equation requires assumptions on e , and WTP is adjusted only for income differences. Lack of reliable information on the income elasticity of WTP is the main weakness of this approach.

In the second approach, the estimated benefit function for the study site is used to compute policy site benefits using the coefficients of the study site benefit function. This approach allows variables, in addition to income, to be used to estimate WTP on the policy site. As many suggest (Loomis 1992; Krupnick 1993; Downing and Ozuna 1996; Kirchoff, Colby, and LaFrance 1997; Brouwer and Spaninks 1999), the benefit function transfer approach is preferred over the direct transfer of benefits. It should be noted that the benefit function transfer approach still requires average values of those variables that were considered in the study site, which affect the project benefits in the policy site. However, despite the need to collect some data, much less effort is required than for an original study. This chapter recommends using benefit function transfer over direct benefit transfer in project preparatory studies.

⁴ Table 6.2 presents transfer errors from the application of the benefit transfer in environmental projects, as reported in selected studies. The application of the CV method for the study site in the original studies is questionable, which can lead to more errors. The recommended application of the CV method in this chapter for urban services, and transferring the benefits to similar sites in a short period of time, may not cause such large errors.

Table 6.2 Estimated Errors Arising from Benefit Transfer: Selected Studies

Study	Valuation technique	Environmental good	Transfer samples	Amount of control in terms of explanatory variables	Transfer error (%) ^a
Loomis (1992)	Zonal TC model	Sport fishing	10	<ul style="list-style-type: none"> • travel distance • fish harvest • fishing quality at substitutes 	5–40 5–15
Parsons and Kealy (1994)	Random utility TC model	Water quality improvements	2	<ul style="list-style-type: none"> • travel costs (including time) • area size • depth of lake • area accessibility • water quality • main recreational use • household income (dummy) 	4–34 1–7.5
Loomis and White (1995)	Zonal TC model	Reservoir-based recreation	3 districts 10, 8, 8 sites	<ul style="list-style-type: none"> • travel costs • area size • availability of substitutes • population size • median age 	.. 1–475
Bergland, Magnussen, and Navrud (1995)	Iterative bidding CV	Water quality improvements	2	<ul style="list-style-type: none"> • bid levels • main recreational use • education (2 dummies) • age (dummy) • user (dummy) 	25–45 18–41
O'Doherty (1996)	Open-ended CV	Green space	2	<ul style="list-style-type: none"> • green space under development • place of residence • income group • awareness of substitutes • main recreational use 	Unknown
Downing and Ozuna (1996)	Dichotomous choice CV	Saltwater fishing	8	<ul style="list-style-type: none"> • bid level • time period (dummy) 	1–34 ^b ..

continued on next page.

Table 6.2 continued.

Study	Valuation technique	Environmental good	Transfer samples	Amount of control in terms of explanatory variables	Transfer error (%) ^a
Kirchhoff, Colby, and LaFrance (1997) ^c	Payment card CV	White water rafting	2 pairs of sites	<ul style="list-style-type: none"> • perceived flow level⁽¹⁾ • expenses/person⁽¹⁾ • use intensity (dummy)⁽¹⁺²⁾ • main reason for visit⁽¹⁺²⁾ • place of residence⁽¹⁺²⁾ • household income⁽¹⁺²⁾ • sex⁽¹⁾ • age⁽²⁾ • education⁽²⁾ 	24–56 6–22

.. = not available, CV = contingent valuation, TC = travel cost.

^a Minimum and maximum absolute transfer errors found in the studies. The first range refers to the difference between observed average unit values at the study site and policy site, and the second range to the difference between the observed average value at the policy site and predicted average value at the policy site based on the benefit function transferred from the study site.

^b Own calculations. In the case of dichotomous choice CV, no observed average sample mean exists. The observed average unit value has to be calculated from the bid function. In Bergland, Magnussen, and Navrud (1995), the average “observed” unit values at the study and policy sites were calculated based on the complete bid functions, including other explanatory variables besides the bid levels. This means that the calculated “observed” average unit values control for significant influencing factors at the specific sites and hence do not correspond with the usual average unit value.

^c The superscripts ⁽¹⁾ and ⁽²⁾ refer to the two different bid functions tested.

Source: Brouwer and Spaninks (1999).

Depending on data availability, three types of benefit transfer are possible:

- (i) across different time periods for the same site,
- (ii) across different sites within the same time period, and
- (iii) transfer to a future timeframe and to a different site.

In all of these cases, benefit function transfer has advantages over direct benefit transfer. Foremost is the use of coefficients from the demand equations or WTP functions from the study site, which provide a way to account for differences in explanatory variables between the study site and the policy site or between different times. In this chapter’s

case study, we apply the benefit function transfer approach from one site to another within the same period. The transfer of benefit estimates from the study site to future subprojects in the same site is also feasible in urban projects.

As shown in Table 6.2, the errors arising out of the application of benefit transfer can be very high under certain circumstances. To ensure that the benefit function transfer method is applied with the rigor needed to minimize errors, the following steps should be followed:⁵

- (i) Specify the definition of the values to be estimated at the policy site. In urban projects, benefits depend on the type of service improvement.⁶ In most project preparatory studies the correct measure of benefits is WTP because a project offers improved service to the community.⁷
- (ii) Identify the most suitable secondary source of WTP function, involving a thorough literature survey.⁸ The attributes of the good or service valued and the socioeconomic characteristics of the policy site must be considered in determining the transferability of benefit estimates from the study site. If service improvements are different in the two sites and the variables that cause such differences are not included in the WTP function, benefit transfer will result in large errors.
- (iii) Examine the transferability of benefit estimates from the identified study site research based on the following criteria:
 - a) The non-market commodity valued at the study site must be identical to that of the policy site; the type of service improvements in the study site and policy site must be the same.

⁵ See Boyle and Bergstrom (1992) and Krupnick (1993) for details.

⁶ The benefits of water supply improvement from 6 hours service to 24 hours service will be different from 12 hours improved service. Similarly, the benefits of a sanitary landfill will be different from an open dump. Such project details are important in defining benefits.

⁷ In some applications of the transfer of environmental benefits, willingness to accept compensation is the relevant measure. The use of WTP or willingness to accept compensation depends on the initial assignment of property rights. When an improved service is offered to a community it has no property right to the service, and WTP is therefore the correct measure. In some cases, if a new factory is going to pollute the air, willingness to accept compensation is the correct measure. Because the community currently owns the clean air, they should therefore receive a payment to compensate for their welfare loss due to air pollution. These two measures have the same efficiency implications, but they have different distributional implications.

⁸ In addition to journal and electronic searches, the analyst should look for unpublished studies. There are many well-done valuation research studies that do not contain the methodological innovations required by many journals for publication. Finding these research studies and various other publications that are not widely circulated is very important at this stage.

- b) The beneficiary population of the urban service improvements in the study site and at the policy site should preferably have very similar characteristics.
- (iv) The test for transferability should lead to the selection of the highest quality and most relevant study from the identified studies. Once the study site is selected, the next step is to evaluate the quality of the benefit estimates at the study site. The quality of the work at the study site determines the success of benefit transfer. If the original benefits are estimated using a CV study, the analyst should make sure that the required standards set out in Chapter 4 are met in the original study. The study site estimates should be evaluated in terms of the theoretical specification of the values, development of CV scenarios, enumerator training, data collection procedures, and the results of validity tests.⁹
- (v) When the quality of benefit estimates at the study site is found satisfactory, the analyst may proceed to collect the necessary data at the policy site. If the information available is to be found in secondary sources with acceptable reliability, the secondary data could be used to calculate benefits at the policy site. In some cases, primary data collection may be necessary at this step. Short surveys with small sample sizes and key informant surveys can be used if primary data collection is inevitable. Once the necessary data are collected, WTP can be estimated by incorporating the average values of policy site data into the WTP function of the study site.

This method of the estimation of benefits is particularly useful in sector and MFF projects.¹⁰ In preparing core subprojects or the first tranche, an original CV study can be undertaken to assess demand and economic feasibility. When subsequent subprojects or tranches are processed, their economic feasibility can be quickly assessed using the benefit transfer method. Since the benefits are estimated for the same population and transferred over time, the possibility for errors is minimized.

⁹ If there is bias at the study site, it might be magnified at the policy site. Therefore, the analyst needs to know the magnitude of the bias at the study site.

¹⁰ When the sector modality is used to develop and implement a project, only a set of representative subprojects is initially subjected to economic analysis. Benefits estimated in these representative subprojects can be used to assess future subprojects. The same principle applies to MFF projects, in which a benefit estimation study can be undertaken during the development of the first tranche and the values can be transferred to future tranches.

6.3 Urban Development Case Study

6.3.1 Introduction to the Case Study

This case study is based on the Hebei Small Cities and Towns Development Demonstration Sector Project, an urban sector project that includes about 10 subprojects in small cities and towns in the province and is slated for completion around 2015. Detailed assessment and analysis has been undertaken for three core representative subprojects: Zhaoxian Subproject, Zhengding Subproject, and Bazhou Subproject (Table 6.3). The original analysis was modified to simplify exposition and illustrate the use of appropriate methods in the context of a multisector project, given the time and other resource constraints practitioners faced. As a result, the level of detail and data analysis differs between subprojects.¹¹ Additional assumptions were made when data were not available. The original analysis of the river improvement component of Bazhou Subproject was modified using hypothetical data.

Table 6.3 Case Study's Core Representative Subprojects

Subproject	Component	Description
Zhaoxian Subproject	District heating	Rehabilitation and expansion of urban heating system, including construction of two central heating stations (382 MW), 20 km of transmission and distribution lines, and district stations
	Solid waste management	Additional 100 tons/day capacity, 2.52 ha solid waste processing and recycling plant
	Wastewater treatment	Doubling of capacity to 100,000 m ³ /day, construction of primary and secondary (biological) treatment works
Zhengding Subproject	Solid waste management	New 4.6 ha solid waste processing and recycling plant; collection and transfer works, including transfer stations, compression trucks, and skips
Bazhou Subproject	Sewerage system improvement	Construction and rehabilitation of 66 km of city sewer networks
	Water supply	Construction of wells, pump stations, 20,000 m ³ /day water treatment plant, and a distribution pipeline network

ha = hectare, km = kilometer, m = meter, m³ = cubic meter, MW = megawatt.
Source: ADB (2009).

¹¹ This implies also that the associated Excel sheets containing the data analysis should not be used as a comprehensive template for analyzing future projects.

In terms of methodology, the case study extends standard practice in ADB appraisals by undertaking a contingent valuation study and applying the benefit function transfer approach to estimating economic benefits.

6.3.2 Economic Rationale of the Project

A macroeconomic analysis and a sector and subsector analysis were undertaken as part of project preparation. This case study focuses on cost-benefit analysis.

The PRC government is committed to developing small cities and towns to foster economic growth, generate employment, and narrow the rural-urban income gap. The development of Hebei Province is anchored on the PRC's 11th Five-Year Plan, which emphasizes the potential of small cities and towns to provide a higher standard of living to rural migrants without exacerbating infrastructure fatigue and other problems afflicting large cities. This policy supports the PRC's vision of a "harmonious society", in which the benefits of economic growth are shared more equitably. Hebei's policy on small city and town development mirrors the national policy. Its 11th Five-Year Plan, 2006–2010 calls for the development of a more balanced urban system through the growth of medium-sized cities that can serve as economic centers for surrounding towns. County-level cities and towns, in turn, are expected to enhance their economic integration with rural areas, which are primarily dependent on agriculture for their livelihood.

The main constraint on town development is inadequate urban infrastructure and services. Towns need more reliable, sustainable water supply and energy services to attract private investment that will create jobs and attract migrants. At the same time, improved wastewater and solid waste disposal are necessary for mitigating the negative environmental impacts of rapid economic growth and improving living conditions for local residents. Industrial development in Hebei Province has outstripped its infrastructure, resulting in environmental degradation and sub-optimal conditions for business development in small cities and towns.

The project will improve urban infrastructure and municipal services to: (i) attract investment in the processing, manufacturing, and service industries in the cities and towns of Hebei's poorer counties; (ii) provide residents a decent urban environment; (iii) strengthen urban

management capacity in planning, implementation, and operation; and (iv) extend the benefits of growth to all.

The project involves public sector intervention at several different levels and its rationale is justified by a number of factors. First, components such as river improvements and public toilets are public goods and non-revenue generating and are, hence, not attractive to private sector investment. Second, other components, such as water supply and wastewater treatment, represent natural monopolies. However, while these components are considered natural monopolies and have the potential to generate revenue, the current tariffs are inadequate for full cost recovery. A drastic tariff increase at the beginning of the project is not politically feasible, and the private sector therefore cannot operate these services profitably at the same tariff levels. Third, many project components result in positive externalities the benefits of which cannot be converted to revenue streams under the current regulatory and institutional set up. Therefore, private sector involvement is not feasible at this point and the project will not crowd out any potential private sector investments.

6.3.3 Assumptions Used in the Analysis

This section describes some of the common assumptions used in the analysis of the subprojects. The economic analysis of each component covers a period of 25 years, inclusive of the construction period. Economic benefits and costs at the domestic price numeraire are in local currency at constant 2008 prices using an exchange rate of CNY6.8 per \$1. Table 6.4 provides the conversion factors used in the analysis.¹² Transfer payments such as taxes and import duties are excluded in estimating the economic costs before applying the shadow price coefficients.

The economic costs of the core components include: capital cost including land acquisition and resettlement, and environmental mitigation and monitoring costs; and operating and maintenance (O&M) costs. Land acquisition and resettlement costs were estimated based on their opportunity costs, that is, the foregone livelihood opportunities (mainly agricultural output) and other resettlement costs. A 12%

¹² These assumptions are based on the *Guidelines for the Preparation of Feasibility Study of Investment Projects* issued by the PRC's National Development and Reform Commission (2002).

discount rate was used in calculating the net present value (NPV). A core subproject component is considered economically viable if the NPV is greater than zero or the EIRR is higher than 12%.

Table 6.4 Conversion Factor Framework for the Appraisal of the Subprojects

Primary inputs	Conversion factors (Domestic price numeraire)
Tradables	SERF = 1.08
Non-tradables	1
Unskilled labor	SWRF = 0.50
Transfers – taxes/subsidies	0

SERF = shadow exchange rate factor, SWRF = shadow wage rate factor.
Source: National Development and Reform Commission, PRC (2002)

6.3.4 Economic Viability of Representative Subprojects

A. Component 1: District Heating, Zhaoxian Subproject

Background. The demand for urban heating has grown rapidly as incomes have increased, residential housing has been privatized, and the housing sector has grown. As incomes increase, people in the PRC's cold regions have demanded better heating facilities; central heating supply grew 19.1% annually from 1996 to 2004. The total heated area of buildings in the country was only 734.3 million m² in 1996, but increased to 2,166.6 million m² in 2004. Residential buildings accounted for 70% of the total space heating demand and commercial and public buildings for the rest. Combined heat and power generation and/or urban central heating supply served only about 35% of residential buildings in the cold regions.

Without-Project Scenario. Similar to the national trend, heating demand in Zhaoxian County has grown rapidly. The Heat Supply Development Plan of Zhaoxian County estimated the number of industries/enterprises would increase from 16 to 20 and heating space for non-residential buildings would increase to 4.13 million m² by 2010 and to 9.06 million m² by 2020. Zhaoxian's central heating station, operated by the Zhaozhou Thermoelectricity Company Limited, serve some 520,000 m² of heating space. Of the population not connected to the central heating system, about 86% use coal for winter heating. A survey

of beneficiary households shows that about 8% (CNY163.3 per month) of household income on average is spent on coal for household heating. The residential heating charge for connected households is CNY17.5/m² (for about 4 months from November 15 to March 15). The present heating network only covers a small area, and most industrial areas are not connected to the system. The existing heat source consists of old small boilers, which are expensive to maintain and have low heating efficiency. The lack of adequate discharge mechanisms in these small boilers causes air pollution.

The Project. The project aims to provide piped heating supply to households, commercial establishments, and industries and increase central heating coverage from 14% to 80% of the population. It will replace existing small inefficient boilers and rehabilitate and expand the existing heating system by constructing 2 heating stations, 20 kilometers (km) of transmission and distribution pipelines, and 63 secondary heat substations. When completed, heating supply capacity is expected to reach about 387 MW, providing heating to 7.3 million m² by 2020, from about 2.9 million m² in 2010. The project encourages households to switch from open coal burning to cleaner and cheaper energy use for heating. Not only will it improve heating during winter, it will also reduce overall air pollution in the urban district, providing significant health benefits. It will also improve fuel efficiency and reduce the cost of heating for households.

Demand Forecast. Zhaoxian County's population of 124,337 in 2010 is projected to increase to 162,232 by 2020. Total heating area was estimated to reach 9,060,000 m² by 2020 from 130,000 m² in 2010, based on projected population growth. The project is expected to serve 80.1% of the heat supply area by 2020 (Table 6.5). The potential income effect was incorporated by changing the size of houses in estimating the demand. The projected total heating area also included an allowance for an increase in non-residential building space together with population growth based on the observed patterns of other towns.

Alternatives Analysis. As mentioned in the engineering study report on the technical feasibility of the project, there are a few alternatives to be considered. The existing Zhaozhou Thermoelectricity Plant and Limin Group Plant provide household heating by using the hot water released by thermal power generation. Given that some plant facilities are underutilized, expansion of heating services can be made without incurring some of the overhead costs that a new scheme would entail.

Table 6.5 Zhaoxian District Heating: Projected Heating Area and Heat Supply

Year	Projected heating area m ²	Heat supply area to be served by the project	
		m ²	%
2010	4,130,000	2,904,000	70.3
2020	9,060,000	7,260,000	80.1

m² = square meter
Source: ADB (2009).

Moreover, because the existing system can provide heating to part of the buildings served by the project without using additional energy, the project saves energy resources, which translates to lower O&M costs and less environmental damage. Because of this special feature of the considered technical option, even if the environmental costs are included in the LCA, expansion of the existing system will be the least-cost option.

Good practice would require comparison of economic costs of different options using LCA. For this case study, the application of least-cost analysis is illustrated for components 3 (wastewater treatment) and 5 (water supply).

Cost–Benefit Analysis. The total estimated financial capital cost is CNY98.19 million and the corresponding economic cost CNY77.44 million (Table 6.6). An important first step in deriving economic costs is to decompose the costs into primary inputs such as tradables, non-tradables (including labor), and taxes/duties. In this case, tradable costs comprise 20% of the investment cost or CNY19.64 million. After deducting import duties, estimated at 10% of foreign cost, the tradable net investment cost is multiplied by the shadow exchange rate factor (SERF) of 1.08 to get its economic cost of CNY19.09 million.

The remaining 80% of the investment cost is assumed to consist of non-tradables, which include local materials and labor. Value added tax of 17% is deducted from the non-tradable investment cost. Of the non-tradable net investment cost of CNY65.20 million, local materials are estimated to account for 70% (or CNY45.64 million). Since the materials are non-tradable and already in domestic price units, no further adjustments are made. Labor cost is estimated at 30% of non-tradable net investment cost, of which unskilled labor accounts for 70%. The unskilled labor cost of CNY13.69 million is adjusted by the shadow wage rate factor (SWRF) of 0.50 to get its economic cost of CNY6.85 million. Skilled labor cost does not have a shadow price as it is assumed that the wages of skilled labor

reflect its market opportunity cost. The total non-tradable economic cost of CNY58.35 million ($= 45.64 + 6.85 + 5.87$) is added to the economic cost of tradables to get the total economic cost of CNY77.44 million.

Table 6.6 Zhaoxian District Heating: Financial and Economic Costs

Primary inputs	Adjustment (Domestic price numeraire)	Economic cost, CNY million
Tradable: Foreign cost – import duties (10%)	Cost * SERF = 17.67 * 1.08	19.09
Non-tradable: Local materials – value added tax (17%)	Cost * 1 = 45.64	45.64
Non-tradable: Labor – unskilled	Cost * SWRF = 13.69 * 0.5	6.84
Non-tradable: Labor – skilled	Cost * 1 = 5.87	5.87
Total		77.44

SERF = shadow exchange rate factor, SWRF = shadow wage rate factor.
Source: ADB (2009).

O&M costs of CNY8.17 million are estimated to start in year 3 and assumed to increase by 5% per year from year 3 to 12, at which time the heat supply capacity of the plant reaches its maximum. O&M costs are assumed to consist only of non-tradables, thus requiring no adjustment except for the unskilled labor component of repair work, which is adjusted by the SWRF.

The benefits from heating consist of resource cost savings (based on the avoided cost of an alternative heating source) and time savings. The estimated population that would benefit from the project—both with existing connections to the heating system and new connections—is about 117,200 in 2008 and projected to increase by 3% per year to reach 162,232 by year 12. At this point, heating demand leads to full capacity utilization, which implies that heating supply remains constant thereafter. The avoided cost of heating is based on the use of coal during the 4-month winter season, which is estimated at CNY163.3 per month, that is, 8% of the monthly average household income of CNY2,042. With the assumption of no incremental increase in heating, only the resource cost savings were considered benefits. However, in cases where there is incremental demand arising from a reduction in price, this incremental heat consumption should be valued at WTP.

In addition to resource cost savings, time savings of 4.5 hours per family were valued using the existing wage rate. It was assumed that unskilled labor is used to fetch coal and the shadow wage rate factor of 0.5 is used to convert the financial value of time savings to its economic value. The reduction in coal use and replacement of small boilers will also provide environmental benefits such as improved air quality due to a decrease in emissions of particulate matters, sulphur dioxide (SO₂), and nitrogen oxide (NO_x). However, the environmental benefits were not included in the calculations. The economic analysis of the base case yielded an EIRR of 23.2%, which would be higher if the environmental benefits were added to the benefit stream.

Sensitivity Analysis. The analysis shows that the EIRR is robust to changes in key variables and assumptions. If time savings are not included, the EIRR will fall only marginally to 21.3%. The EIRR is most sensitive to lower connection rates, which is a signal for project authorities to make sure that the beneficiary populations are aware that the project will provide better service at lower financial costs and reduce indoor air pollution. Table 6.7 provides a summary of the results of the economic analysis and sensitivity analysis.

Table 6.7 Zhaoxian District Heating: Economic Viability and Sensitivity Analysis

	Change	ENPV (CNY '000)	EIRR (%)	Switching value (%)
Base case		60,242	23.2	
Capital cost	+20%	47,599	19.6	95
Operating and maintenance cost	+20%	47,213	21.0	92
Population growth rate	from 3% to 1%	41,271	20.6	-4
Lower household connections	80% only	28,912	18.0	
No time savings		49,509	21.3	

ENPV = economic net present value, EIRR = economic internal rate of return.
Source: ADB (2009).

B. Component 2: Solid Waste Management, Zhaoxian Subproject

Background. Zhaoxian County is largely agricultural, with 78% of the total land area of 675 square kilometers (km²) devoted to agriculture. A waste characterization study for the county showed that biodegradable

waste accounts for about 54% of total waste volume and recyclables 12%. Garbage per capita is estimated at 1.28 kg/capita/day, which is projected to decrease to 1.0 kg/capita/day in 2019 as living standards improve and lifestyles change.¹³

Without-Project Scenario. The project area generated about 152 tons of waste per day in 2006. Solid waste collection coverage was 60%, with eight small tractors and 74 tricycles collecting and transporting waste to two landfill sites. Phase 1 of the solid waste processing facility was completed in 2008. The facility's garbage operating machines undertake sorting, crushing, biochemical fermentation, drying, milling, and sieving. Associated facilities include mixture exchange reactors, granulators, and support facilities such as electrical and heating systems, and water supply. It is estimated that the Phase 1 plant capacity is insufficient to accommodate the future needs of Zhaoxian County's population, which was assumed to have grown 5% during 2006–2010 and to grow 3% from 2011 to 2020. The county's total waste generation is projected to increase from 195 tons/day in 2010 to 258 tons/day in 2020.

The Project. Phase 2 of the project aims to provide additional waste processing capacity to reduce the waste material sent to disposal sites as much as possible. In addition to environmental benefits, the project can significantly extend the life of the landfill sites. The project will increase waste collection coverage to 100% by 2015, from 60% in 2006, and divert biodegradable and recyclable materials to the proposed solid waste processing facility.

The project will entail construction of a solid waste treatment plant with an estimated total floor area of about 10,865 m², consisting of a measurement/weighing facility, and a primary treatment facility, including receiving, bag breaking, and sorting. Its fermentation section will include a facility for making organic fertilizer and a treatment facility for plastic waste. The processing facility will be located about 3 km south of Zhaoxian town. It is estimated that the processing plant will have the capacity to produce 18,600 tons of organic fertilizer, 2,000 tons of recycled plastics, 175 tons of recycled glass, 115 tons of recycled metals, and 36,500 tons of other wastes per year. The service area of the proposed solid waste treatment facility includes the (i) residential area of Zhaozhou town, (ii) Zhaozhou industrial area, (iii) Chengguan

¹³ Analysis of household garbage in more than 500 cities in the PRC conducted by the Chinese Environmental Science Institute revealed that small cities generate about 1.0 to 1.3 kg/capita/day of garbage.

industrial area, (iv) the agricultural area south of Xiao River, and (v) the residential area north of Zhaozhou town.

Alternatives Analysis. The main treatment option being considered is composting, integrated with recycling and partial land filling. Different composting technologies such as anaerobic composting and aerobic composting were assessed. Aerobic composting was found to cost less than anaerobic composting, which would also require more land and produce inferior compost. Thus, aerobic composting technology is adopted for the waste processing plant.

Two different types of aerobic treatment technology were assessed: a forced draft dynamic bar system and storehouse ferment system, the latter being the chosen option for Zhaoxian. Although it has the highest cost (about 20% more in investment but 10% less in O&M costs), it ferments in less time, occupies less land, needs fewer personnel, and has higher compliance levels in comparison to the forced draft dynamic bar system. Other factors considered in the selection included (i) higher organic content of generated waste, (ii) similar technology as in Phase 1, (iii) local climatic suitability for fermentation, and (iv) reuse and recycling of waste materials.

Estimation of Benefits. Project benefits come from two sources: revenue from the sale of recycled waste materials (plastic, glass, metal, etc.) and organic fertilizer made from biodegradable waste; and benefits to households and commercial establishments from solid waste management. The benefits from the sale of recycled waste materials and organic fertilizer are based on the market price of recovered materials. The solid waste management component will promote safe and hygienic disposal of solid waste, reduce sewer and drain blockage, and reduce the concentration of airborne particulates arising from burning garbage. Piles of garbage in public places will be reduced, improving the environment in Zhaoxian County. For households and commercial establishments in the project area, the risk of disease and illness associated with an unhygienic environment and water-related disease is expected to decline. The benefits to households and commercial establishments—the removal of waste from the vicinity and safe disposal—were estimated using the results from a CV survey, the details of which include:

- (i) **Pre-characterization of the existing solid waste management situation.** A detailed characterization study was carried out using available literature and field work (informal discussions, field observations, and interviews of government officials). The

- characterization focused on (a) the physical characteristics of the service area and solid waste, (b) economic factors, (c) the current system of solid waste management, (d) institutional factors, and (e) the impact on health of existing solid waste management.
- (ii) **CV scenario.** The CV market scenario describes what the project is planning to do, after discussing the existing solid waste management services, which include service coverage area, effects of poor solid waste management on people's health, and environmental problems brought on by poor solid waste management.
 - (iii) **Payment vehicle.** The monthly solid waste management charge (bill) was used as the payment vehicle.
 - (iv) **Elicitation method.** A closed-ended, single-bounded CV question asked whether the respondent is willing to pay a specified amount as the value of the improved solid waste management service. The answer to the CV question is either “yes” or “no”.
 - (v) **Bid distribution.** The initial bids were based on actual costs and the proposed solid waste tariff the Zhaoxian County government planned to implement. Respondents were presented with a randomly assigned bid (monthly bills of CNY3, CNY4, CNY6, CNY8, and CNY10) and asked whether they were willing to pay the given bid amount for the improved solid waste management in the form of monthly bills.
 - (vi) **Sample.** A random sample of 500 households and commercial establishments¹⁴ were interviewed during the survey, treating the service area of households and commercial establishments as the population. The final analysis was carried out for 484 respondents, after excluding questionnaires found wanting in data integrity.
 - (vii) **Survey instrument design.** The preliminary survey instrument was developed based on a similar study conducted in Sri Lanka. This preliminary version was modified using information from the feasibility study report, particularly the technical assessment report of the Zhaoxian solid waste treatment plant, local conditions in the study area, existing and potential levels of service, financial data on capital and operating and maintenance

¹⁴ A sample size of only 500 was included since the study was undertaken under severe resource and time constraints. It is good practice to have a bigger sample of about 2,000 households.

costs, and the secondary information used to characterize the solid waste situation in the study area.

- (viii) **Pre-tests.** The preliminary survey instrument was pre-tested on 50 households drawn from the target population. The most important modification to the draft survey questionnaire pertained to the range of monthly bids for the contingent valuation question. The high-end bid was raised to CNY10 per household per month because the highest bid in the original version was not rejected by a high enough percentage of respondents.
- (ix) **Survey implementation.** With a consultant providing field supervision, a Hohai University professor administered the survey assisted by seven students as enumerators. The enumerators were trained to become familiar with the survey instrument and CV method. This involved an introduction to the economic concepts underlying the study, the basic elements of the CV study and its relevance, pilot interviews using the preliminary version of the questionnaire, group discussions, and pre-testing.
- (x) **Data management.** The consultant developed a coding sheet and demonstrated the data entry procedures to the field supervisor. The consultant constantly monitored data entry and performed random checks to avoid errors.
- (xi) **Validity tests.** To undertake validity tests, a set of independent variables hypothesized to affect WTP for better solid waste management were included in the regression model as explanatory variables. The results of the validity tests, estimation of the mean WTP, and demand analysis are discussed below.

In estimating the WTP function, the independent variables in the regression model consisted of household income, age of household head, education level of household head, gender of respondent (male = 1, female = 0), type of dwelling (apartment = 1, individual house = 0), size of yard, health impacts of poor SWM (households which experienced solid waste-related sickness = 1, otherwise = 0), and respondent's evaluation of existing SWM agency (very poor = 1, poor = 2, neutral = 3, good = 4, very good = 5).

Income and education were expected to have a positive effect on WTP while the bid was expected to have a negative effect. The age of the

household head was assumed to have a negative impact on WTP. A bigger yard would allow waste disposal by the household and therefore was assumed to have a negative relationship with WTP. Those households that had experienced sickness related to poor SWM were assumed to have higher WTP. Households with negative perceptions about the existing SWM agency may have lower WTP. The gender variable was added to examine whether it influences WTP.

The results of the probit regression show that price (bid) has a strong and negative impact on WTP, income has a positive impact (Table 6.8), and age has a negative impact. The remaining variables are not statistically significant. The two most important variables that determine demand and WTP—price and income—show the expected relationship; therefore, the results adequately validate the survey data. Using the regression results and the method described in Chapter 3, the mean WTP was estimated to be CNY7.18249 per month per household. This represents the perceived benefit of the described solid waste management regime to the households.

Table 6.8 Zhaoxian Solid Waste Management: Mean Willingness to Pay

Variable	Coefficient	Mean	Coefficient x mean
Bid	-0.19779		
Income	0.00002	24,501	0.48468
Education	-0.00826	10.6070	-0.08765
Gender	0.04213	0.4938	0.02080
Age	-0.01020	43.2710	-0.44149
Yard	0.00146	121.6800	0.17805
Type of dwelling	0.11087	0.58058	0.06437
Health impact	-0.07108	4.3822	-0.31146
Performance rating	-0.12587	3.0434	-0.38307
Constant	1.8968		1.89640
Total			1.42062
Mean willingness to pay			7.18249

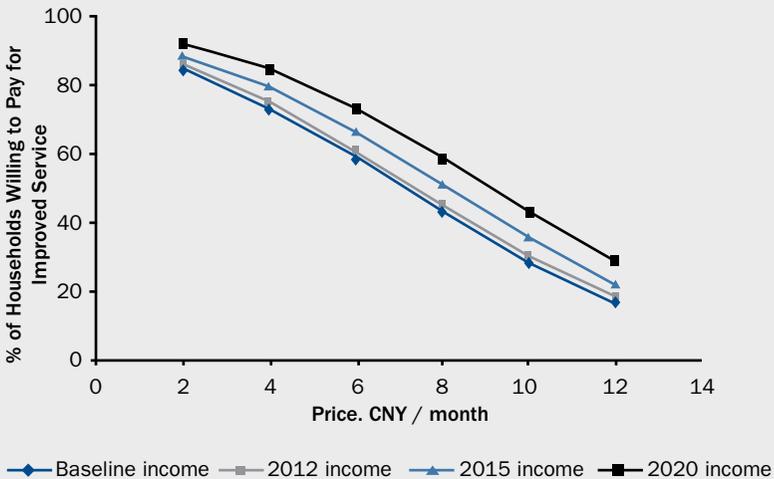
Source: ADB (2009).

The mean WTP is estimated as follows: (i) for all variables (except the bid), multiply the coefficients by the mean; (ii) get the total of the products of the coefficient and mean; (iii) divide the total by the bid

coefficient and multiply by -1 . Thus, mean WTP = $1.42062 / -0.19779 * -1 = 7.18$. To estimate the benefits to households, the mean WTP is multiplied by the projected number of households to be served by solid waste management services.¹⁵

Effective Demand. Demand generally refers to the relationship between the price and quantity of a commodity. The demand curve shows the prices people are willing to pay for different quantities of a commodity. The price–quantity relationships for solid waste management were obtained from the responses to the elicitation question, where the x-axis represents the bid or the proposed monthly solid waste bill and the y-axis represents the percentage of households that agree to pay the proposed monthly bill to receive the service. The acceptance rate (or uptake rate) is a proxy for quantity in the usual price–quantity relationship. The estimated WTP function is used to predict demand under different future scenarios. In this case, the regression model was

Figure 6.1 Zhaoxian Solid Waste Management: Demand at Different Income Levels



Baseline income = CNY24,501 per month; projected average monthly household income = CNY27,012 (2010), CNY34,475 (2015), CNY44,000 (2020).

Source: ADB (2009).

¹⁵ Usually, benefit estimation considers the population of the service area. A better way is to predict the uptake rate and use this rate in estimating the benefits. Such prediction requires future changes in the variables of the WTP function. This type of data is generally not available in developing countries. Moreover, regulatory requirements and institutional and governance regimes require all households to be a part of the new system. Therefore, considering the population in the service area may not lead to large errors.

simulated for future income changes under various bids. As shown in Figure 6.1, there is a considerable increase in demand when incomes increase. For example, at the current average income, only 59.2% of the respondents agree to pay the monthly solid waste bill of CNY6, rising to 73.2% when income increases to the 2020 level.

The predicted uptake rates assuming voluntary acceptance of the service can be used to estimate potential revenues that can be collected from the households. The revenue is calculated by simply multiplying the predicted number of households by the bid/tariff (Table 6.9).

Table 6.9 Zhaoxian Solid Waste Management Predicted Revenues

Tariff CNY/month	Predicted revenue, CNY million/month			
	Base year income	2010 income	2015 income	2020 income
2	0.97	1.03	1.23	1.46
4	1.68	1.81	2.20	2.68
6	2.03	2.21	2.76	3.48
8	1.99	2.19	2.84	3.73
10	1.65	1.84	2.48	3.42
12	1.17	1.32	1.86	2.71

Note: Revenue refers only to monthly bills for solid waste collection; it does not include revenue from recyclable/biodegradable waste.
Source: ADB (2009).

Two important features emerge from the results. First, maximum tariff revenue is CNY6 up to 2010, but rises to CNY8 per month per household after that. Second, revenue is higher at each tariff as income increases over time. These results can be used to compare revenues and the costs of solid waste collection. However, caution is needed in selecting the tariff because a tariff maximizing revenue may not maximize environmental objectives. For example, at CNY6, only about 59.2% of households in the baseline year and 61.2% in 2010 will voluntarily participate in the program. If the solid waste of households that do not participate in the program is not collected and disposed of, the objective of a cleaner city will not be achieved. Therefore, to ensure that most of the garbage is collected, a tariff that is less than the revenue-maximizing tariff may be desirable. Since the percentage of households willing to

accept the service increases with higher incomes, the tariff can be increased over time.

The major portion of the total benefit (about 74% in present value terms) of the SWM project is derived from the material recovery and organic fertilizer. The benefits to the household are only about 26% of the NPV. The cost of material recovery is also high, as represented by the higher O&M costs of about 64% in present value terms. The results of the economic analysis show that the proposed solid waste treatment plant (Phase 2) is economically justified, with an EIRR of 19.6% and a net present value of CNY24.1 million. Table 6.10 presents the results of the sensitivity analysis. Sensitivity tests indicate that the project is robust; the EIRR is above 12% even in the worst-case scenarios. The project benefits are somewhat sensitive to the O&M costs, but these should increase by about 36% for the EIRR to fall below 12%.

Table 6.10 Zhaoxian Solid Waste Management: Economic Viability and Sensitivity Analysis

Scenario	NPV @ 12% (CNY million)	EIRR (%)	Switching value (%)
Base case	24.1	19.6	
Capital costs			64.0
10% increase	20.4	17.9	
20% increase	16.6	16.5	
50% increase	5.3	13.2	
Operating & maintenance Costs			36.2
10% increase	17.5	17.6	
20% increase	10.8	15.5	
50% increase	-9.2	8.8	
Mean WTP			-72.9
10% decrease	20.8	18.7	
30% decrease	14.2	16.7	

EIRR = economic internal rate of return, NPV = net present value, WTP = willingness to pay.
Source: ADB (2009).

C. Component 3: Wastewater Treatment, Zhaoxian Subproject Background. Zhaoxian County has targeted 100% coverage of wastewater treatment by 2020. River water quality is poor, caused mainly by chemical

pollutants, which have exceeded the environmental limits set by the government. Surface water entering the county from upstream is also heavily polluted. In recent years, water resources have continued to be seriously damaged by untreated industrial and domestic wastewater generated within the county and surrounding areas. At present, industrial wastewater accounts for 89% and households for 11% of total wastewater generation of 28 million m³ per year.

Without-Project Scenario. The first wastewater treatment plant (WWTP) commissioned in 2006 has a design capacity of 50,000 m³/day. While it has relieved the deterioration of the interior environment in the core urban area, it has not fully addressed water pollution from sewage generated by the growing population and industrial activity. Polluted rivers and waterways have caused mosquitoes and flies to breed, threatening the health and life of the residents. Rivers have become silted over time, which has affected normal drainage of rainwater, leading to stagnant waterways. These waterways are a source of irrigation for agriculture however, the polluted water affects the quality of produce, including the health of consumers. The quality of the physical environment has also been affected by the foul smell emitted from stagnant waterways. Without the project, these problems will worsen.

Starch processing and papermaking are the main industrial enterprises in the county. Industrial wastewater accounts for about 80%–90% of total wastewater volume generated in the service area. The first WWTP has not been operating efficiently. The actual pollution load of wastewater far exceeds the designed inlet water quality, which means that some enterprises have not installed/operated pollution treatment facilities. In the absence of the proposed project the wastewater situation will continue to deteriorate.

The Project. The project is designed to treat wastewater with heavy pollution loads to match the current quality of influent. The project will involve a separate drainage system for rainwater and sewage. Under this scheme, rainwater will be discharged into the nearest receiving water bodies, while sewage will be directed to the sewage treatment plant. After sewage is treated, the plan is to use recycled water for urban landscape irrigation and street cleaning and to discharge any residual into the Xiao River. The project will use existing interceptor pipes from the combined drainage network of the first WWTP. The project will use a new technology which will treat large volumes in a small land area by using a single basin for primary settling and secondary (biological)

treatment. Compared with the Biolak¹⁶ technology adopted in the first WWTP, the new technology includes a hydrolysis step to break down organic matter, and requires less energy and maintenance.

The design of the new WWTP will effectively reduce pollutants in heavily polluted wastewater (Table 6.11). The residual sludge produced from the biological treatment section will be pumped into a concentrated squeeze dewatering integrated machine and disposed of in a landfill. The project is estimated to benefit about 150,000 people by 2015.

Table 6.11 Zhaoxian Wastewater Treatment: Projected Reduction in Pollutants

Pollutant	Annual decrease (tons/year)
Chemical oxygen demand	15,512.5
Biological oxygen demand	5,292.5
Suspended particles	7,117.5
Nitrates	151.3
Phosphates	629.6

Source: ADB (2009).

Alternatives Analysis. The project will initially replace the existing WWTP. As the quality of influent improves due to the project, the existing plant may be able to function together with the new plant. Three secondary treatment processes, namely, improved A²/O-UCT, ORBAL, and sequencing batch reactor-cyclic activated sludge system (SBR-CASS) have been identified and examined with respect to engineering capability and functional performance. Through the engineering assessment and preliminary cost comparison, two process alternatives were shortlisted for further evaluation including least-cost analysis: improved A²/O process-UCT (engineering preferred option) and SBR-CASS process (comparative option). The major components of the first consist of A²/O reaction tank, final settling tanks, intermediate pumping station, filters, ultraviolet (UV) disinfection contact tank, sludge treatment room, and sludge pumping station. For the second option, the major components consist of tanks with a simple repeated sequence of aeration and non-aeration to provide aerobic, anoxic, and anaerobic process conditions; filters; and UV disinfection contact tank; sludge treatment room; and sludge pumping station.

¹⁶ This technology was developed by Shandong Biolak Environment Science & Technology Co., Ltd. It uses an aerobic stabilizing plant with simple automatic pre-treatment facility.

The lifecycle financial costs, including capital investment costs and O&M costs associated with the two identified options, have been converted into economic costs by applying appropriate conversion factors (Table 6.12). The O&M costs shown in the table represent annual cost at full capacity utilization. The present value of the total costs show that the SBR–CASS process is the least-cost option.

Table 6.12 Financial and Economic Costs of Process Options (CNY ‘000)

	Option 1: A2/O–UCT process		Option 2: SBR-CASS process	
	Financial	Economic	Financial	Economic
Capital Cost	63,296.29	54,368.50	57,516.10	50,100.40
Civil works	28,330.30	20,807.37	22,507.50	16,530.77
Equipment	13,580.80	12,510.72	14,240.00	13,117.98
Installation costs	4,248.68	3,913.91	4,022.50	3,705.55
Supervision and other fees	11,382.30	11,382.30	11,382.30	11,382.30
Physical contingency	5,754.21	5,754.21	5,215.20	5,215.20
Other	148.60	148.60	148.60	148.60
Operating and Maintenance		9,200.48		8,900.30
Present value of Costs		115,250.41		109,111.34

SBR–CASS = sequencing batch reactor–cyclic activated sludge system, UCT = University of Cape Town.
Source: ADB (2009).

Other measures were incorporated in the project design to ensure that the selected option would have lower costs. For example, the second WWTP will be adjacent to, and west of, the first WWTP. Since both plants will be managed together, the plants can be operated with the minimum number of new operational staff. As wastewater volumes increase over time, the treatment technology for the first WWTP will be upgraded to conform to the new technology of the second WWTP. The location will also enable the use of the auxiliary production facilities of the existing plant, thereby reducing investment cost and shortening the construction period. Additionally, reserve land in the area of the existing WWTP will be used for the project, avoiding the need to buy new land.

Estimation of Benefits. The benefits of the wastewater treatment project were estimated using the same CV survey described above. The specification of the regression equation for the plant was similar to that of solid waste management, except for the inclusion of dummy variables

for currently connected households (connected = 1, otherwise = 0) and for houses with septic tanks (without septic tank = 1, otherwise = 0).

Households with septic tanks have already invested in safe wastewater disposal and therefore may have lower WTP. Currently connected households may have different WTP compared to the unconnected. The results in Table 6.13 show that price (bid) has a statistically significant negative relationship with WTP and income a positive relationship. Age also has a negative effect on WTP, while people in apartment buildings have higher WTP. Households without septic tanks perceive higher benefits from the plant. The regression results are generally consistent with theoretical expectations and adequately demonstrate the validity of the CV data. The mean WTP for wastewater treatment is estimated to be CNY2.40 per m³, derived using the same method described for component 2 on solid waste management.

The benefit stream is based on the incremental volume of treated wastewater, that is, the difference in the volume of treated wastewater with and without the project. With the project, a total of 85,000 m³ per day of wastewater will be treated in 2011, increasing to 96,500 m³ per day in 2015. Without the project, the volume of treated wastewater is equivalent to the 50,000 m³ per day of the existing capacity of the first plant. The computed mean WTP of CNY2.40 per m³ is then multiplied by the incremental volume of treated wastewater to estimate the economic benefits.

Table 6.13 Zhaoxian Wastewater Treatment: Regression Results and Mean WTP

Variable	Coefficient	Standard error	t-ratio	Mean	Coefficient x mean
Bid	-0.45086	0.050860	-8.8646 **	6.1959	
Income	0.000010088	0.0000052137	1.9349 *	24,501	0.2472
Education	0.015059	0.022724	0.66268	10.607	0.1597
Age	-0.017986	0.0061295	-2.9343 **	43.271	-0.7783
Gender	0.077438	0.13122	0.59015	0.4938	0.0382
Type of dwelling	0.35557	0.14603	2.4350 **	0.581	0.2066
Connection	0.12294	0.27444	0.44796	0.9296	0.1143

continued on next page.

Table 6.13 continued.

Table 6.13 Zhaoxian Wastewater Treatment: Regression Results and Mean WTP					
Variable	Coefficient	Standard error	t-ratio	Mean	Coefficient x mean
Septic tank	0.45288	0.24260	1.8668 *	0.0873	0.0395
Performance rating	-0.058961	0.073410	-0.80318	3.1612	-0.1864
Constant	1.2417	0.56065	2.2147 **		1.2417
Total					1.0826
Mean WTP					2.4012

* Estimated coefficient at 10% level of significance, ** estimated coefficient at 5% level of significance.
WTP = willingness to pay.
Source: ADB (2009).

Effective Demand. Based on the above results, effective demand (% of households and commercial establishments willing to pay for the service) for wastewater treatment is predicted using the WTP function. Results reveal (Figure 6.2) that demand is highly price sensitive; even at a low tariff of CNY1 per m³, only about 74% of water users are willing to pay for the service. If the tariff is increased to CNY5 per m³, only 12% of water users are willing to pay. This price sensitivity may be largely because the monthly wastewater treatment bills of industrial establishments are comparatively high due to their release of large quantities of wastewater.¹⁷ However, the wastewater charge is very affordable. For example, assuming that the tariff is pegged at CNY2.50 per m³, a household with average water consumption of 10 m³ per month for domestic use¹⁸ and a wastewater generation rate of 80% will have a monthly wastewater bill of CNY8, which accounts for only 1.5% of an average monthly income of CNY1,500 of poor households. Industrial establishments and businesses that use large volumes of water and contribute more to the pollution load do not face affordability issues.

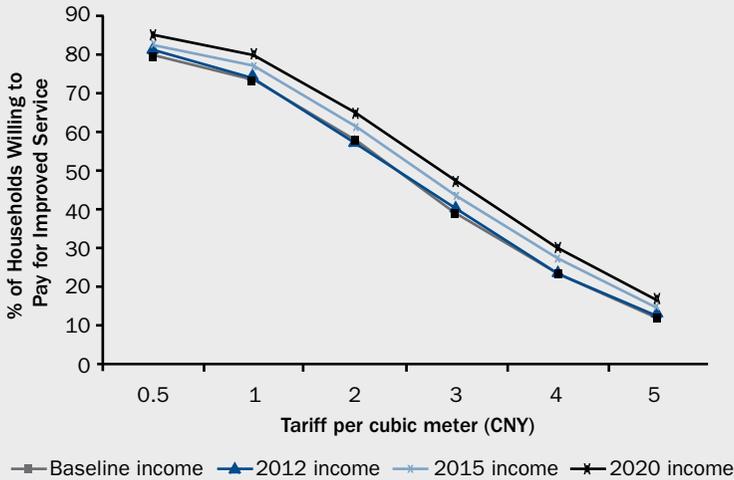
As income increases, households' WTP likewise increases (Figure 6.2). However, the demand for wastewater treatment is not very sensitive to income changes. For example, at the price of CNY1 per m³, only 74%

¹⁷ Note that many households also own industrial and business establishments.

¹⁸ Current average household use of water is about 5 m³ per month

of households demand the wastewater service at their current income. At the 2020 income level and the same price, demand increases to only about 80%.

Figure 6.2 Zhaoxian Wastewater Treatment: Demand at Different Income Levels



Baseline income = CNY24,501 per month; projected average monthly household income = CNY27,012 (2010), CNY34,475 (2015), CNY44,000 (2020).
Source: ADB (2009).

Cost-Benefit Analysis. The economic investment cost was estimated at CNY50.1 million, that is, after deducting taxes and duties and adjusting the financial investment cost to economic cost using shadow price coefficients. The benefit stream was calculated assuming that the full capacity of the plant is reached in the sixth year of the project. The EIRR for this component is estimated at 33.5%. The results of the sensitivity analysis in Table 6.14 show that project benefits are sensitive to mean WTP. However, mean WTP needs to fall by 56% to reduce the EIRR to 12%.

Table 6.14 Zhaoxian Wastewater Treatment: Economic Viability and Sensitivity Analysis

Scenario	NPV (CNY '000)	EIRR (%)	Switching value (%)
Base case	83,711	33.5	
Capital cost			202
10% increase	79,560	30.9	
20% increase	75,108	28.7	
50% increase	62,953	23.6	
Operating & maintenance cost			155
10% increase	78,323	32.2	
20% increase	72,934	30.9	
50% increase	56,768	26.9	
Mean willingness to pay			-56
20% decrease	47,888	25.0	
30% increase	29,977	20.4	

EIRR = economic internal rate of return, NPV = net present value.
Source: ADB (2009).

D. Component 4: Solid Waste Management, Zhengding Subproject

Background. Waste generation in Zhengding County in 2006 was estimated at 210 tons/day, of which biodegradable waste accounted for 54%, non-biodegradable 36%, and recyclables 10%. The rate of waste generation is assumed to follow the trend in population growth, at 5% per year from 2006 to 2010 and 3% from 2011. Visitors to the county, which is a tourist attraction, generated 140 tons/day of waste in 2011, increasing 7.5% per year up to 2020 (based on the rate of increase of tourist arrivals). From 2020 to 2025, solid waste generation by tourists will increase 3% per year and remain constant thereafter.

Without-Project Scenario. In 2006, only about 65%–70% of generated waste was collected and disposed in the present landfill, which cannot absorb all generated waste in the long run. In the without-project scenario, therefore, more and more waste will be left uncollected as waste volume grows.

The Project. The project will construct a solid waste treatment plant with an estimated total floor area of 45,900 m², consisting of a

measurement/weighing facility; primary treatment facility including receiving, sorting, bag breaking, and so on; fermentation facility including a fertilizer making unit; and a treatment facility for plastic waste. The plant will have the capacity to produce 39,900 tons of organic fertilizer, 5,050 tons of recycled plastic, 860 tons of recycled glass, 560 tons of recycled metals, and about 18 million bricks per year. Plant capacity is designed to process 500 tons of waste a day. It is projected that households will generate 484 tons/day by the end of the project's economic life (2033) while another 100 tons will come from industry. At the beginning of the project, about 35% (135 tons/day) of plant capacity will be used to process household waste, gradually increasing to about 63% (310 tons) by 2033. Remaining plant capacity will be used to process waste generated by tourists.

Alternatives Analysis. The main treatment process is composting, integrated with recycling and part land filling. The analysis considered different composting technologies, such as anaerobic composting and aerobic composting, with the latter found to cost less. The same technology as in Zhaoxian County was selected as the least-cost option for the same reasons.

Estimation of Benefits. The benefit function transfer method—from one site to another in the same province at the same time—was used to estimate the benefits from improved solid waste management. The WTP function developed for Zhaoxian together with the relevant data from Zhengding were used to estimate the benefits for households and commercial establishments. The following details justify the use of this method and ensure that errors are minimized:

- (i) **Definition of benefits.** Benefit is valued at WTP. The two solid waste management schemes in the study site (Zhaoxian) and the policy site (Zhengding) are identical; the same improvements are undertaken using the same technology in both.
- (ii) **Source of WTP function.** The original CV study was conducted by the same project preparatory team for the same purpose in a nearby location.
- (iii) **Transferability of benefits.** Since the proposed service improvement is identical, the commodities in the two sites are identical. Moreover, the beneficiary populations in Zhaoxian and Zhengding have very similar characteristics and the transfer is taking place in the same time period.

- (iv) **Quality of the original study.** The original study was designed and conducted using the methodology specified in Chapter 4, and the validity test results are satisfactory.¹⁹
- (v) **Policy site data.** For the same variables used in the Zhaoxian site, mean values need to be obtained for the Zhengding site. The mean values for income and education level were obtained from secondary sources. The accuracy of these data was also verified with the available official records in the county. Mean age and gender distribution were assumed to be the same as in Zhaoxian. Focus group discussions, field observations, and key informant interviews were held to decide the mean values of the type of dwelling, area of yard, health impact, and performance rating of the existing services.

Table 6.15 shows the coefficients and means for variables from the CV study in Zhaoxian, along with the mean values obtained for Zhengding. The coefficients for Zhaoxian are then multiplied by the means for Zhengding. The sum of the products of the coefficients and mean (1.26686) is then divided by the bid coefficient (-0.19779) and multiplied by -1. The estimated mean WTP for Zhengding solid waste services is thus CNY6.41 per household per month, which is lower than the figure of CNY7.18 for Zhaoxian. The difference is mainly attributable to the income difference. The economic benefits are then estimated by multiplying the mean WTP by the number of households served because the mean WTP reflects the economic value of the improved services.

Cost–Benefit Analysis. The economic capital cost of the project was estimated at CNY68.5 million. The O&M costs of the project increase over time because the processing plant initially operates below full capacity. Given that the chemicals required to process the waste are proportionate to the amount of waste, O&M costs increase over time. The benefit stream is comprised of two major components: (i) household benefits from collection and safe waste disposal; and (ii) the value of the materials recovered from waste processing. The results of the economic analysis show that the proposed plant is economically justified, with an EIRR of 21.3% and a net present value of CNY47.3 million. Table 6.16 presents the results of the sensitivity analysis.

¹⁹ In the case of transferring the WTP function from an unknown study, full details of the original study should be provided and its quality examined to ensure that benefit transfer does not lead to large errors.

Table 6.15 Zhengding Solid Waste Management: Mean WTP through Benefit Transfer Function

Variable	Coefficient for Zhaoxian	Mean for Zhaoxian	Mean for Zhengding	Coefficient for Zhaoxian * mean for Zhengding
Bid	-0.19779			
Income	0.00002	24,501	22,438	0.44387
Education	-0.00826	10.60700	10.89000	-0.08999
Gender	0.04213	0.49380	0.49380	0.02080
Age	-0.01020	43.27100	43.27100	-0.44149
Type of dwelling	0.11087	0.58058	0.43000	0.04767
Yard	0.00146	121.68000	102.64000	0.15019
Health impact	-0.07108	4.38220	3.83000	-0.27222
Performance rating	-0.12587	3.04340	3.88000	-0.48838
Constant	1.89640			1.89640
Total				1.26686
Mean WTP				6.40509

WTP = willingness to pay.
Source: ADB (2009).

Table 6.16 Zhengding Solid Waste Management: Economic Viability and Sensitivity Analysis

Scenario	NPV (CNY '000)	EIRR (%)	Switching value (%)
Base case	47,297	21.3	82
Capital costs			
10% increase	41,546	19.5	
20% increase	35,795	18.1	
50% increase	18,541	14.6	
Operating & maintenance			48
10% increase	37,514	19.5	
20% increase	27,731	17.7	
50% increase	(1,619)	1.6	
Mean willingness to pay			-78
20% decrease	35,096	19.1	
30% decrease	28,996	18.0	

EIRR = economic internal rate of return, NPV = net present value.
Source: ADB (2009).

E. Component 5: Water Supply, Shengfang, Bazhou Subproject

Background. Shengfang County, under the jurisdiction of Bazhou City, consists of 39 villages. It has 5,400 business enterprises and is the largest producer of steel and wood furniture in the country. The urban center is expected to expand from 17 km² in 2006 to 35 km² in the short term and to 54 km² in the long term, with the development of residential and industrial areas.

The population grew 5% annually during 1998–2002. With the development of industrial zones, the population grew 5.5% per year during 2007–2010 and 4.5% in 2010–2020. Thus, the population was projected to reach 196,000 in 2010 and 272,000 in 2020. While the feasibility study estimated a total water requirement of 40,000m³/day by 2010, the project preparatory technical assessment team deemed 2015 more likely.

Without-Project Scenario. The existing water supply system delivers about 15,500 m³/day to 90,000 residents out of a total population of about 155,000, including transient industrial workers. The existing system has 13 operational wells with a yield of 65 m³/hour per well and a plant capacity of 20,000 m³/day. It serves the old town and the southeast industrial zone. Current water use is mainly for domestic activities and for enterprises requiring treated water, such as the food industry. At present, the total water requirement is 30,000 m³/day and is higher than current supply. Households connected to the system receive intermittent service 3 times a day (for a total of about 9 to 10 hours a day). The leakage rate is 30% owing to old pipelines (installed in 1958) and bursts due to water pressure from intermittent supply. Unconnected households have shallow wells while hospitals, businesses and others supplement their need with deep wells. The unregulated extraction of groundwater raises sustainability concerns.

Many households buy water for drinking and only use tap water for cooking and washing. Many complain about the poor quality of water as manifested in foul smell, poor taste, and turbid appearance. Also, the old pipelines are incapable of supplying appropriate water pressure for fire fighting in the new development areas. Moreover, high fluoride content causes yellow teeth and brittle bones. High levels of salinity in shallow wells also make it difficult to meet drinking water standards. As there are no standards for the construction of private wells, water quality is questionable. The water company subsidizes operations because of low tariffs, low collection rate, and high leakage. The local government

considers insufficient water supply a major constraint on the growth of enterprises.

The Project. The project aims to: (i) support and promote economic development through the expansion of industry and increased incomes, (ii) improve health conditions, and (iii) promote water conservation. The project will serve the existing service area and expand coverage to the northwest part of Shengfang town and the northeast industrial zone, bringing the total service area to 35 km². The main components of the project include the drilling of 14 deep wells, construction of pump stations and a water treatment plant (with a capacity of 20,000 m³/day), and installation of 47 km of pipelines to expand the network. Urban households and residents of the industrial areas will be given connection priority. Large-scale industries will be supplied with recycled water. The Shengfang Water Company is rehabilitating existing pipelines with local funding, with completion expected in time for the commissioning of the project. The rehabilitation of pipelines is expected to reduce the leakage rate to below 10%.

Alternatives Analysis. Two sources of water were considered: surface and ground. But the surface source, the Daqing River and its tributaries, was found unsuitable due to seasonal fluctuations in volume, and pollution from untreated wastewater and run-off from agricultural fields. Dry weather for many years has lowered water levels in these rivers, with some drying up, and industrial development has polluted waters, requiring extensive water treatment if they are to be tapped for domestic use. The sustainability of groundwater sources is based on the assumption that industry's self-provided wells will be significantly reduced after the second wastewater treatment plant is completed, which will bring total capacity to 50,000 m³/day and generate 20,000 m³/day of recycled water to be used by industry.

Table 6.17 shows the cost of water from the two sources. The average incremental cost (AIC)—present value of economic costs divided by the present value of quantity of water—shows that the groundwater-based project is the least-cost option. Its AIC of CNY1.5/m³ is lower than that of the surface water option. The recommended option is to use groundwater in Xibei, a new village which has a large aquifer. Economic activity close to the source is controlled and there is limited exploitation of resources in the area. To serve the entire town, the long-term plan is for water supply to connect to the regional south-to-north water diversion project, which would then replace the groundwater sources.

Table 6.17 Cost of Water with Alternative Sources

Year	Groundwater option		Surface water option	
	Cost (CNY '000)	Water quantity (m ³)	Cost (CNY '000)	Water quantity (m ³)
1	21,300	0	15,117	0
2	24,627	0	18,140	0
3	3,190	3,380	18,140	0
4	3,240	3,944	9,070	5,700
5	3,240	4,507	1,266	5,700
6	3,240	5,071	1,266	5,700
7	3,240	5,634	1,266	5,700
25	3,240	5,634	1,266	5,700
Present value	58,550	38,966	52,718	27,393
AIC (CNY/m³)	1.5		1.92	

AIC = average incremental cost, m³ = cubic meter.
Source: ADB (2009).

Estimation of Benefits. The estimated economic benefit of water supply in Shengfang is based on the results of the CV survey conducted in Kazuo County (Liaoning province). In applying the benefit function transfer method, location-specific data collected in Shengfang using focus groups, key informant surveys, and published secondary data were used to estimate the mean WTP for improved water supply services. The original survey found that mean WTP is quite different between connected and unconnected households. For connected households, it is CNY2.79 per m³ and more than double the CNY5.91 per m³ for unconnected households.²⁰

Table 6.18 shows the mean WTP calculations for connected and unconnected households using estimated coefficients from Kazuo. The same procedures as illustrated for the Zhengding solid waste management project are used. An extra step is to calculate the weighted figures for connected and unconnected households, using the proportion of these beneficiaries in the service area as weights. The weighted mean WTP of CNY4.66 per m³ for water services is used to value the total projected consumption of households, which is based on an average assumed use of 10 m³ of water per month.

²⁰ The original CV survey included commercial establishments in the sample. However, only about 10% of the beneficiaries were commercial establishments. Their values on water are embedded in the mean WTP.

Table 6.18 Shengfang Water Supply: Mean WTP through Benefit Function Transfer

Variable	Connected households			Unconnected households		
	Coefficient for Kazuo	Mean for Shengfang	Coefficient * mean	Coefficient for Kazuo	Mean for Shengfang	Coefficient * mean
Bid	-0.90763			-0.60479		
Income	0.00003	24,216	0.76130	0.00003	24,216	0.76741
Education	0.03233	8.23000	0.26603	-0.05867	8.23000	-0.48283
Age	0.00850	40.40000	0.34347	-0.01122	40.40000	-0.45325
Gender	-0.07612	0.58500	-0.04453	-0.21248	0.58500	-0.12430
Type of dwelling	0.42261	0.29032	0.12269			
Water scarcity				0.26618	3.57980	0.95287
Ethnicity	0.24411	0.98000	0.23923	0.32617	0.98000	0.31965
Constant	0.84517	1.00000	0.84517	2.59690	1.00000	2.59690
Total			2.53337			3.57644
Mean WTP			2.79119			5.91353
Weighted Mean WTP (all households)						
	Mean WTP		Share	Weighted		
Connected	2.79119		40%	1.11648		
Unconnected	5.91353		60%	3.54812		
Mean WTP				4.66460		
WTP = willingness to pay.						
Note: Type of dwelling is not considered under unconnected households because this is a newly developing area. Water scarcity is not considered under connected households because they get an adequate amount of water, although the quality of water, reliability, and service quality are poor.						
Source: ADB (2009).						

Cost-Benefit Analysis. The EIRR was estimated considering: (i) an economic investment cost of CNY45.92 million, that is, after deducting taxes and duties and applying conversion factors to financial prices; (ii) operating and maintenance costs (economic) of CNY3.24 million per year; and (iii) a benefit stream based on an additional capacity of 20,000 m³ per day of treated water by 2015. In estimating the benefits, it was assumed that a household consumes 10 m³ of water on average. The EIRR is estimated to be 33.7%. Table 6.19 presents the results of the sensitivity analysis. The project benefits are not very sensitive to cost

escalations and to lower mean WTP. The project becomes economically non-viable only if the estimated mean WTP is 60% or more below the original estimate. The EIRR is quite sensitive to the quantity of water consumed. However, it is economically viable even if water consumption remains at the current level of 5 m³ per month.

Table 6.19 Shengfang Water Supply: Economic Viability and Sensitivity Analysis

	NPV (CNY '000)	EIRR (%)	Switching value (%)
Base case scenario (10 m ³ per month)	86,348	33.7	
Water consumption			
7.5 m ³ per month	50,124	25.5	
5 m ³ per month	13,899	16.2	
Capital cost			223
10% increase	82,483	31.2	
20% increase	78,618	29.2	
Operating & maintenance			434
10% increase	84,358	33.2	
20% increase	82,368	32.7	
Mean willingness to pay			-60
20% decrease	57,368	27.2	
30% decrease	42,879	23.8	

EIRR = economic internal rate of return, m³ = cubic meter, NPV = net present value.
Source: ADB (2009).

6.3.5 Summary of Economic Analysis Results

In addition to the above analysis by project component, the entire project was subjected to cost-benefit analysis. In examining overall viability, other costs that cannot be attributed directly to each project component were included. For this case study, the sector project involved a capacity development component which included institutional strengthening and recurring costs related to project management. These common costs, amounting to about CNY44.0 million, are assumed to be

disbursed over 5 years and were converted to economic costs through the application of the appropriate conversion factors for each primary input category.

Table 6.20 shows that the individual projects are economically viable with EIRRs ranging from 19.6% to 33.5%. Even when the common costs are included, the entire project's EIRR of 23.9% is well above the discount rate of 12%.

Table 6.20 Summary of Economic Viability

Project Components	ENPV (CNY '000)	EIRR (%)
Zhaoxian: District heating	60,242	23.2
Zhaoxian: Solid waste management (Phase 2)	24,138	19.6
Zhaoxian: Wastewater treatment plant (Phase 2)	83,711	33.5
Zhengding: Solid waste management	47,298	21.3
Bazhou: Shengfang town water supply	86,348	26.4
Overall Project	272,400	23.9

ENPV = economic net present value, EIRR = economic internal rate of return.

Source: ADB (2009).

6.4 Concluding Remarks

The main challenge in the economic analysis of an integrated urban development project is the presence of many sectors, which requires large amounts of data and time. The chapter demonstrated pragmatic approaches for accomplishing this difficult task within a limited timeframe. The chapter demonstrates the use of the benefit transfer method in the context of a sector project in which the WTP function estimated in one subproject is used to derive the benefits in another subproject for a similar site at the same time. The chapter recommends the use of the benefit function transfer method under similar circumstances to minimize errors. If the source WTP study is undertaken by the same team as in this case, the guidelines provided in Chapter 4 should be followed. If a secondary source is used, that study should be thoroughly reviewed to ensure that it meets the standards set in Chapters 4 and 5.

7. Economic Analysis of Transport Improvements

7.1 Methodology

This chapter reviews the approach to the economic analysis of transport projects, focusing on road projects and providing a detailed illustration of how to conduct a road appraisal. Drawing on recent literature, as summarized in a series of Transport Notes (such as World Bank 2005a, 2005b, 2005c, and 2005d; HEATCO 2005), it sets out the approach to practical appraisals widely used by international agencies. The case study shows how relatively simple improvements can be applied to increase the analytical rigor of the standard approach to appraisals, as exemplified in an actual road project that is reworked in detail here.

7.1.1 Approach for Transport Project Evaluation

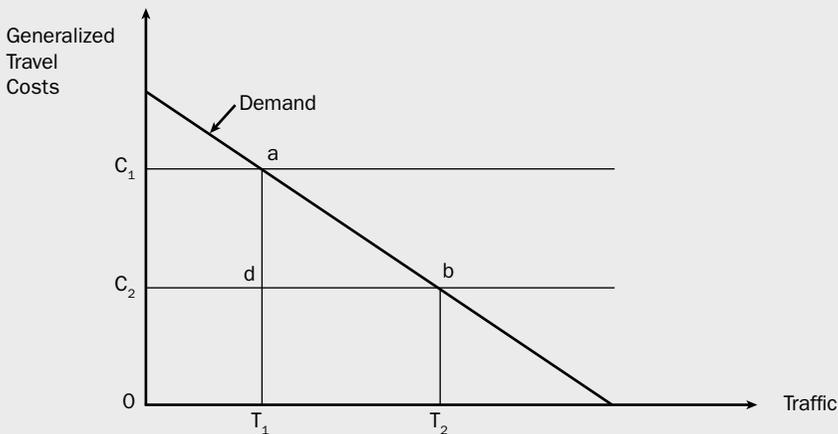
Transport projects—normally covering road, rail, and port sectors—can be highly complex due to their broad inter-relations with other sectors of the economy. Practical appraisals normally omit wider general equilibrium effects, focusing on more tangible partial impacts. Their output corresponds clearly to the “incremental/non-incremental” distinction used in the Asian Development Bank’s *Guidelines for the Economic Analysis of Projects* (ADB 1997), but what is unique is that in transport projects, the willingness-to-pay (WTP) measure of benefit for incremental output is normally based on an estimate of cost savings.

In the setting of incremental and non-incremental benefits, the non-incremental output corresponds to “normal traffic” which would have

used a route or other existing mode in the absence of the new project and traffic diverted from another route(s) by the cost savings and convenience of the improved transport facility. The incremental output, will be “generated traffic” stimulated by the low costs of the new project. In Figure 7.1, normal and diverted traffic is represented in the horizontal axis from 0 up to T_1 whereas $T_2 - T_1$ represents generated traffic. The y axis represents generalized travel costs that include vehicle operating costs (VOCs) and time costs. C_1 and C_2 , respectively, represent the generalized travel costs without and with the transport project.

In the simplified but widely used approach to estimate the benefits of a transport project, a linear demand curve and a horizontal supply curve is assumed. As shown in Figure 7.1, the area C_1abC_2 represents the total welfare gain from the transport improvement. The total benefits can be separated to non-incremental (area C_1adC_2 = cost difference times the normal traffic) and incremental benefits (area abd = cost difference times generated traffic times half). This standard approach to value normal traffic at generalized cost savings and generated traffic at half of cost savings forms the basis for estimating the benefits of transport projects.

Figure 7.1 Estimating Benefits through the Rule of Half



The full benefits of a transport improvement may include accident cost savings and operating and maintenance (O&M) cost savings on the transport system depending on the specific cases where such benefits accrue. Incremental and non-incremental distinction is not

made in estimating accident cost reduction benefits, owing mainly to the difficulties of attributing the accidents to normal and generated traffic. Depending on the without-project scenario, O&M savings in the transport system can also be added to the benefits.

The benefits of generalized travel cost savings (B) are thus:

$$B = (C_1 - C_2) * 0T_1 + 0.5(C_1 - C_2) * (0T_2 - 0T_1) \quad (1)$$

and by rearranging, this reduces to:

$$B = 0.5 (C_1 - C_2) * (0T_2 + 0T_1) \quad (2)$$

so that benefits equal the sum of with-project traffic and without-project traffic multiplied by half VOC savings (“the rule of half”).

It is well known that this treatment of generated traffic is a simplification and that the size of the error will be related to the size of the VOC reduction created by the project and the degree to which the demand–price relationship departs from a linear form. The larger the cost reduction and the more convex or concave the demand–price relation, the larger the error. The theoretically correct solution is to integrate the demand function with respect to the change in cost/price to calculate the change in consumer surplus. This will only be possible, however, if the demand function is known as a continuous function over the range of cost/price change, which in practice is rarely the case. Hence, the ‘rule of half’ is a common simplification that is judged adequate for cost reductions up to approximately one-third, and where projects do not create major structural shifts in traffic flows and wider economic activity. Moreover, the horizontal supply curve indicates that the marginal cost of adding extra traffic to the transport facility is zero. While this may not be a concern up to a point of traffic increase, congestion may set in beyond a certain point and marginal cost may increase resulting in an upward sloping supply curve.

This chapter focuses on the economic analysis of road transport due to the fact that the bulk of transport investments in developing countries supported by development banks are in road transport.¹ In principle, the same valuation methodology focusing on vehicle or user cost savings for existing traffic and half of these per unit for diverted and generated traffic can be applied to transport projects, other than roads, most

¹ For example, as of July 2011, road transport accounts for about 73% of ADB’s loans to the transport and information and communication technology sector. ADB has shifted its focus toward more integrated urban transport schemes so that in future the expectation is that, while they will remain important, future standalone road projects of the type examined in this chapter will fall as a proportion of the total transport portfolio.

obviously in the rail sector. However, as discussed below, it should not be used for very large cost reductions (more than one-third) or where a project creates a shift of users from one transport mode to another (for example, from a ferry to a road, or from rail to road). The rule of half is also difficult to apply in the context of rural roads where the new road is equivalent to a modal switch since motorized transport links were not previously available.

The major alternative to the above-described method is to consider the economy-wide impacts of transport improvements. Production function, cost function, and profit function approaches are generally used to estimate the impacts of public transport investments on the economy. The impact in these studies is generally measured in terms of output elasticity. The output elasticity—the percentage change in gross domestic product (GDP) per 1% change in transport capital—provides a measure of benefits. However, these approaches suffer from significant analytical and measurement shortcomings.² These methods are more suitable to assess entire investments on infrastructure in a country or a province, rather than assessing individual projects. Moreover, application of these methods in developing countries during a project preparatory study will be severely constrained by time, resource, and data limitations. Therefore in this chapter, we suggest that the use of the traditional method, together with some pragmatic modifications, is acceptable in *ex ante* cost–benefit analysis. The following subsection describes potential improvements in demand forecasting, estimation of project economic life, estimation of project benefits, incorporation of environmental impacts, and incorporation of secondary or stimulated developmental benefits.

7.1.2 Demand Forecasting

As with projects in most sectors, forecasting the demand for transport service is both critical to an appraisal and generally the most approximate aspect of the analysis. For large transport projects with important effects on the choice of transport mode, time of travel, and origin-destination flows (such as urban ring roads or metro systems),

² See Banister and Berechman (2000) for the empirical estimates of output elasticity and a good discussion on the limitations of economy-wide approaches for evaluating transport investments.

relatively sophisticated multi-modal transport models will be required.³ Further, the relatively long working life of road projects compared to those in many other sectors makes forecasting up to the end of project life particularly uncertain.

In practice, with regard to most ADB and World Bank appraisals, demand forecasting is still relatively crude. The standard procedure for a road improvement project for example, is to conduct traffic counts and surveys on the existing network at different times of the day. Weights are then applied to derive a daily average traffic flow for different months or periods within the year. These monthly figures must then be adjusted for seasonal factors—for example relating to the weather, agricultural cycles, or holiday periods—to give a seasonally adjusted average annual daily traffic (AADT) figure. The survey data should allow this AADT figure to be broken down by vehicle type (at a minimum between cars, trucks, buses, motorcycles, and non-motorized transport), with estimates of the proportion of journeys for work and leisure, respectively. Detailed origin-destination flows and travel times, current accident numbers and types may also be recorded.

Forecast traffic flows are often simplistically based either on an extrapolation of past trends or on an assumed income elasticity of demand linking forecast GDP growth with traffic. Assumed income elasticities tend to be in the range of 1.0 to 1.5, with often a higher figure used for passenger than for freight traffic. Generated traffic is then taken as a proportion of total forecast traffic (often between 10% and 20%). This approach is very approximate for a number of reasons:

- (i) Income elasticities will vary between vehicle types and more careful calculations require applying different figures to cars, trucks, buses, and motorcycles.⁴
- (ii) Normal traffic is the traffic that would have used the route in the absence of the project and it is misleading to use the same traffic growth rates for the without-project scenario because of the likelihood of rising vehicle operating costs due to inferior road quality and longer journey times due to increased congestion. How far traffic growth will slow down in the without-project

³ For details of "variable demand models" of this type, see UK Government Department for Transport WEBTAG at www.webtag.org.uk/webdocuments/3.

⁴ Despite the use of different income elasticities, this is still a simplification. Different factors will drive demand growth for different types of traffic in different locations; thus, detailed project calculations should attempt to estimate their impact on future traffic, rather than relying on general income elasticities.

scenario will be determined by price (or the cost increase), and availability of substitute routes, not the income elasticity.

- (iii) The scale of diverted and generated traffic (which in total is “induced traffic”) will also be determined by price elasticity, which is likely to vary between vehicle types, and with the nature of the journey and time of travel.

One of the major weaknesses of demand forecasting in the current practice of transport project evaluation is the exclusion of the price effects on demand. The combination of income and price elasticity in forecasting can be seen in a simple equation for future traffic for traffic type x in year t :

$$T_{xt} = (T_{x0} * [1+g]^y) * (C_{xt}/C_{x0})^n \quad (3)$$

where T_{xt} is traffic flow (AADT) for type x , t is a future year, 0 is the base year, g is GDP per capita growth rate, y is income elasticity of demand, C is generalized travel costs including any toll payments, and n is a constant price elasticity

Both price and income elasticities will in turn vary between vehicle type and trip purpose with the usual assumption that work-related demand will be less responsive to price than demand for leisure travel. Therefore, estimation of future traffic should be done separately for different vehicle types and trip purposes. For illustration, base traffic is set at 100 and GDP per capita growth at 4%, with an income elasticity of demand of 1.2, and a vehicle operating cost reduction of 20%. Price elasticity of demand n is taken as -0.6 .

Putting these values into the elasticity formula gives:

$$\begin{aligned} T_{xt} &= (100 * [1.04]^{1.2}) * (0.8/1.0)^{-0.6} \\ T_{xt} &= 100 * 1.048 * 1.143 \\ T_{xt} &= 119.8 \end{aligned}$$

The above illustration shows that traffic grows by about 20%, with income and price having a multiplicative rather than an additive effect (i.e., growth is 19.8%, not the sum of the separate effects 4.8% plus 14.3%).

The use of price and income elasticities in this type of exercise is only an approximate substitute for model-based forecasting (see Box 7.1). Price elasticities will not normally be known with any accuracy, and for simplicity this formulation assumes constant elasticity. The important general point is that transport appraisals typically define benefits in terms

Box 7.1 Estimating Elasticities

Estimation of elasticities requires detailed survey information on transport users. In principle, there will be a range of price and income elasticities varying between types of transport users; for example, those using public buses, private cars, and commercial vehicles. Empirical estimation requires specifying a demand function for the type of transport involved (for example, total vehicle-km per passenger car) in a zone or between points A and B in a given period so that

$$T = f(Y, G, Z) \quad (B1)$$

where T is the measure of transport use, Y is user income over the period, G is a measure of travel cost, and Z is a vector of variables reflecting household characteristics other than income (such as number of family members, house location, occupation of household head, and so forth).

Cost G must be generalized total cost, which for passenger car owners will cover vehicle operating cost, toll charges, travel time, and any parking cost. For bus passengers, costs will be travel and waiting time, walking time to pick up the bus, and bus fares. When equation (B1) is estimated across a sample of transport user households, travel use (demand) is a function of income, cost (as a proxy for price), and other household characteristics. A common demand function uses logarithmic values so that it is estimated as

$$\ln T = \alpha + \beta_1 \ln Y + \beta_2 \ln G + \beta_3 \ln Z + \epsilon. \quad (B2)$$

where \ln is natural logarithm and ϵ is an error term or residual.

The convenience of this double-log specification is that the coefficients on the explanatory variables are constant elasticities, so that β_1 is income elasticity and β_2 is price elasticity. β_2 is “own price elasticity” in that it reflects the change in transport use for a change in cost for the form of transport service involved. Equation (B1) assumes that the cost of other forms of transport (for example, bus journeys) has no impact (for example, on car travel). A more complex version will include the cost of alternative forms of travel G' so that

$$T = f(Y, G, G', Z). \quad (B3)$$

When equation (B3) is estimated in double-log form, the β coefficient on G' is the “cross price elasticity” for the form of transport use, reflecting how use changes with costs of other forms of transport. More detailed analyses can also disaggregate vector G into a set of different prices, such as fuel cost, tolls, driver wages, parking cost, and so forth. Different elasticities may apply to these different price elements. Table B7.1 shows estimates of elasticity of car trips and car-km with respect to changes in fuel price alone for the European Union. These are in the range -0.20 to -0.40 depending on the type of trip. The average of -0.30 is a consensus figure for the long-run elasticity of traffic volume (vehicle-km) with respect to fuel price, as identified in the major survey by Goodwin et al. (2004) and recommended for use in traffic forecasting in the UK. However, fuel is only a part of total vehicle operating

continued on next page.

Box 7.1 continued.

cost (around 60% in the case study examined in this chapter) and the case study uses elasticity for traffic with respect to generalized cost. Generalized cost elasticities tend to be location-specific and fewer estimates are available than for the fuel price. The database of elasticities compiled by the Victoria Transport Policy Institute (Litman 2009) cites -0.5 as a commonly used value. This is consistent with scaling up the fuel price elasticity of -0.3 , to reflect the fact that fuel is roughly 60% of total cost. It is likely to be relatively conservative since there are estimates of -1.0 for Australia and between -0.5 to -1.0 and between -1.0 to -2.0 for the US, for short- and long-run values, respectively (Litman 2009).

Table B7.1 Long-run Elasticities with Respect to Fuel Price: European Estimates

Type of Trip	Car-km with Respect to Price	Car Trips with Respect to Price
Commuting	-0.23	-0.14
Home-based business	-0.20	-0.07
Nonhome-based business	-0.26	-0.17
Education	-0.41	-0.40
Other	-0.29	-0.15
Total	-0.26	-0.19

Source: De Jong and Gunn (2001). See Chapter 6 of Cameron (2005) or other econometrics texts for estimation of constant elasticities.

of cost reduction of various types and it is illogical not to incorporate the impact of this cost—and by implication, price—reduction in forecasts.

For empirical work such as ADB appraisals, what is required is elasticity with respect to the “generalized cost” of travel (that is, all relevant costs including a valuation of time). No unique value is available⁵ for this elasticity, and a simple practical expedient is to use a baseline value of -0.5 (reflecting an average from the literature) and then to test for the switching value of this parameter (i.e., the price elasticity at which the project becomes marginal) to see if this is implausibly low.⁶

What is suggested here is to consider the interaction between income elasticity and price elasticity in forecasting total traffic growth. The term

⁵ It would be a worthwhile investment for donors to undertake studies to estimate price and income elasticities of traffic growth in countries where they make major investments in the transport sector.

⁶ This is an average of estimates for different types of elasticity; see for example Litman (2007) and Chapter 1 of Quinet and Vickerman (2004).

$(1+g_t)^y * (C_{xt}/C_{x0})^n$ represents the demand factor of traffic. The difference between total traffic growth and normal traffic growth can be used as a proxy for generated traffic. In applying the above formula for normal traffic forecast, the rate of decline caused by congestion and inadequate maintenance levels in the without-project scenario, should be taken into account. The adjustment of normal traffic forecasts for congestion and inadequate maintenance is illustrated in the actual case study presented in the latter part of this chapter.

7.1.3 Estimation of Project Benefits

A. Vehicle Operating Cost Savings

As previously explained, the benefits of transport facility improvements are defined in terms of cost savings. For road projects, these are VOC savings plus time savings and savings for non-motorized transport. For rail, they will be savings on the rail network. For road projects, the main elements of cost savings for vehicles will be fuel and oil, depreciation, tires, and spare parts. Time savings, which are part of the generalized cost savings, include that of the crew for commercial freight, and of drivers and passengers for private cars and commercial buses. For non-motorized transport (such as bicycles, carts, and pedestrian walking time), the main cost savings will be in time and possibly some savings in depreciation due to less wear and tear.

VOC savings will vary considerably by vehicle type—and good practice requires at a minimum a distinction between cars, trucks, buses, and motorcycles—with, if possible, a further distinction by engine size. VOC savings by vehicle type will vary with factors like road surface, gradient, speed of travel, and quality of maintenance. For most road projects in developing countries, VOC savings are calculated using the World Bank Highway Development and Management 4 (HDM-4) model, which also covers non-motorized traffic (see Box 7.2).

Technical data on road and vehicle characteristics plus local prices (for example, for replacement of vehicles and tires, and cost of fuel and labor for maintenance and driving) are entered in the model to derive estimates of cost savings. The HDM-4 model is a highly useful tool, but it is designed to be incremental and is not directly applicable to large projects that create a major structural change in a sector. A

Box 7.2 Highway Development and Management and Roads Economic Decision Models

The Highway Development and Management (HDM) model is useful for several aspects of road planning including generating data on vehicle operating cost (VOC) savings, which can be used as exogenous data in project spreadsheet calculations, as well as in the HDM model itself to calculate project returns. It also provides insights into issues of road maintenance and congestion. VOC will depend on vehicle type, distance, terrain, and road surface, both with and without a road project. The HDM software requires the project analyst to enter basic data on road and vehicle characteristics, as well as unit prices for the key cost items. Origin–destination survey data will also be required on vehicle usage with and without the project. The main items needed for the HDM model are as follows:

Road characteristics	Vehicle Characteristics	Costs
<ul style="list-style-type: none"> • Rise (m/km) • Fall (m/km) • Curvature (degrees/km) • Roughness (m/km) • Width (meters) • Surface moisture content for gravel/earth surfaces (%) • Rut depth • Rainfall (mm/year) 	<ul style="list-style-type: none"> • Average speed (km/hour) • Vehicle weight (tons) • Power to weight ratio (bhp/ton) • Vehicle usage and age (km, years) 	<ul style="list-style-type: none"> • Vehicle price, new • Tire price, new • Price of fuel and lubricants (per liter) • Cost of maintenance labor (per hour) • Vehicle crew cost (per hour) • Overhead

Table B7.2 gives an example of HDM output for VOC for different vehicle types and two alternative measures of road quality—the international road roughness index (IRI) reflecting the with- and without-project scenario. Data come from an unpublished study on an ADB road project in Cambodia.

Table B7.2 Vehicle Operating Cost Comparisons

Vehicle Type	\$/vehicle-km, With Project (IRI = 2.2)	\$/vehicle-km, Without Project (IRI = 7.0)
Car, medium	0.225	0.249
Bus, light	0.207	0.227
Bus, medium	0.353	0.433
Bus, heavy	0.456	0.532
Truck, light	0.182	0.203
Truck, medium	0.286	0.324
Truck, heavy	0.579	0.636
Truck, articulated	0.773	0.862

IRI = international road roughness index, km = kilometer.

continued on next page.

Table B7.2 continued.

The Roads Economic Decision Model (RED) is designed for traffic volumes of 50 to 300 vehicles per day on poor quality roads for which little detailed data exist. It simplifies the analysis by considering a constant level of service for the with and without cases over the period of analysis, whereas the HDM model includes road deterioration equations varying with roads conditions, traffic and other factors. However within RED the relationship between VOC, speed and road roughness derived from the HDM-4 (in the form of cubic polynomials) can be used with exogenous country specific data to derive user benefits. As in this case study generated traffic is derived endogenously by applying a price elasticity of demand to the decrease in total transport cost.

The RED model is set up as a series of Excel Workbooks which provide a framework within which an economic analysis can be carried out. This is clearly a helpful way of allowing a rapid analysis, but it also imposes restrictions which are not present in a spreadsheet model created for a specific project. For example, the RED model works only with a project life of up to 20 years and its risk analysis is based only on a triangular distribution.

Source: For further information, see PIARC's Highway Development and Management Model (HDM-4) Documentation and Software at <http://hdm4.piarc.org/>, and R. Archondo-Callao (2004).

simpler model, the Roads Economic Decision Model (RED) has also been developed at the World Bank specifically for low-volume rural roads, covering all basic aspects of economic analysis of road projects in a standard format.

B. Time Savings

Time saving is a potentially important factor in most transport projects. Detailed estimates of time saved can only be obtained from origin-destination surveys undertaken as part of project preparatory studies. These will highlight driver and passenger time involved in journeys and allow estimates of potential savings where speed levels rise with a new project. Driver and crew time saved for commercial vehicles and buses will already be included in VOC savings from the HDM-4 model, so double-counting must be avoided. However, once time saved has been estimated it must be valued and its monetary value must be included in cost savings. In the context of Organisation for Economic Co-operation and Development (OECD) economies, various revealed preference (behavior-based) or stated preference (survey-based) studies are available to value time, but precise measures are very difficult to obtain in the context of

developing countries.⁷ In principle, valuation of time savings will vary with a range of factors, such as skill levels and wages of workers, income of passengers, and length and discomfort of journey (see Box 7.3).

In practice within most appraisals, working time is valued in relation to either the specific wage of the workers involved (drivers, conductors, and guards, for example) or, more crudely, at the national average wage. In addition, strictly overhead costs of employment (like pension and, holiday costs), where they can be identified, must be added. Where appropriate, the sum of overhead costs and the wage must be converted to economic prices by a shadow wage conversion factor. Hence, the cost per hour of working time (T_w) is

$$T_w = (w + O) * SWRF \quad (4)$$

where w is the hourly wage, O is overhead costs (pension, holidays) per hour, and SWRF is the shadow wage rate factor. In principle, there can be a range of wage conversion factors varying with types of worker, although in practice a single factor for the unskilled is often applied.

For non-working time, the basis for valuation is less clear. While in principle, revealed or stated preference approaches are required in practice, most appraisals value non-working time as a proportion of working time. In the case of working time, the opportunity cost of lost time is the wage, and valuation is based on the wage rate. However, non-working time cannot be meaningfully valued using the wage rate. Household income is a better measure on which to base the value of non-working time. In its Transport Notes for the appraisal of transport projects, the World Bank (2005c) identifies simple rules of thumb that value adult passenger or driver non-working time at 30% of household income per capita and a child's non-working time at 15%. Walking or waiting time saved is to be valued at 50% more than time saved while in a vehicle.⁸

However, it is made clear that for a given income, time values can vary significantly between different social and cultural contexts, since what is being proxied are individuals' valuation of their own time. For example, the World Bank (2005c) also cites a study on Bangladesh where a stated preference survey found respondents stating they valued non-

⁷ See HEATCO's *Developing Harmonised European Approaches for Transport Costing and Project Assessment* (2006) for a survey of studies on time valuation in the European Union. This is another important area for development agencies to undertake research and develop a knowledge base in the countries where they invest in transport projects.

⁸ The original source of these rules of thumb is Gwilliam (1997).

Box 7.3 Estimating Time Savings

Time savings can be estimated from origin–destination surveys. Its value can be approximated using the relevant hourly wage for working time or a proportion of household income per capita for non-working time. Alternatively, time savings can be valued using the contingent valuation methodology to estimate travel user willingness to pay for faster travel time. The latter, while theoretically rigorous, is only recommended for projects where time savings constitute the main benefit. More detailed analyses may identify separately time that would have otherwise been spent in congested (for example, in traffic jams) or crowded (on overcrowded buses) conditions on the grounds that time saved is valued more highly than the norm by those affected. To account for congestion, a 50% premium over the normal value of time saved is a rule of thumb recommended for the European Union (HEATCO 2006). Table B7.3 shows the kind of data required to estimate and value time savings.

Table B7.3 Estimating Time Saving: Data and Valuation

Category	Data to be Collected for Without-Project Scenario	Valuation Basis for Time Saved
Driver/crew work time	<ul style="list-style-type: none"> • Proportion of journeys that are work trips • Average vehicle occupancy 	<ul style="list-style-type: none"> • Driver/crew wage
Driver/passenger non-work time	<ul style="list-style-type: none"> • Proportion of journeys that are leisure trips • Proportion of journeys that are commuting trips • Average vehicle occupancy 	<ul style="list-style-type: none"> • Proportion of driver/passenger wage • Survey-based contingent valuation where leisure time savings are significant
Commercial goods	<ul style="list-style-type: none"> • Proportion of goods traffic by vehicle type, mode, and type of goods 	<ul style="list-style-type: none"> • Driver/crew wage • Survey-based contingent valuation where time savings are important for the products concerned
Congestion	<ul style="list-style-type: none"> • Percentage of travel time per trip spent in congested traffic • Percentage of passengers travelling in crowded conditions 	<ul style="list-style-type: none"> • Premium over normal time value for drivers and passengers

Sources: World Bank (2005c) and HEATCO (2006) Chapter 4.

working time at about 60% of working time. Where time savings are an important component of benefits, a survey of users to estimate the value of time is necessary. Where they are a relatively minor proportion of benefits, a simple rule of thumb, such as taking 30% of household income per capita for adults and a child's non-working time at 15%, are adequate. Detailed estimates for the cost of travel time for business and leisure for various types of journeys in the European Union also suggests that the value of leisure time is in the range of 30%–50% of work time (HEATCO 2006, S12-S13).

Valuation of time—both working and non-working—will rise in real terms over the life of a project with increasing productivity (relevant for working time) and rising average income (relevant for non-working time). To incorporate these real changes in an appraisal, time cost savings should be increased annually. The exact rate of increase will vary with sector productivity growth and the income elasticity of demand for leisure, but a reasonable approximation is to increase time values by the annual growth rate in average real productivity. As with other cost savings, time savings for generated traffic should be measured at half that for normal traffic.

C. Accident Cost Savings

A change in numbers of accidents as a result of a project can also be a significant aspect of some transport projects, creating a benefit in the form of cost savings (where accidents are reduced) and a cost (where they increase). While in the past these effects received relatively little attention in a development context, there is now a greater recognition of their potential importance and of the need to estimate their monetary equivalent value as a project externality.

The approach generally used for valuation of accident costs first separates mortality and morbidity effects of accidents. Mortality effects are generally valued using the human capital approach, which accounts for lost wages of a premature death.⁹ Valuation of non-fatal accidents often distinguishes between “casualty-related” and “accident-related” costs. The casualty-related costs should be estimated as a sum

⁹ See Freeman III (1993) for details of the valuation of mortality and morbidity effects. The human capital approach, despite its theoretical simplification, provides a reasonable proxy for practical purposes. A more sophisticated approach—statistical value of life—can also be used to value the cost of accidents.

of the costs of averting behaviour (use of helmets, for example), lost wages, medical expenses, and disutility of pain and suffering. In actual applications a reduced version of this method, which accounts for costs of lost wages and medical expenditure only is included in the estimation. Costs of averting behavior and cost of disutility of pain and suffering are not included. However, if a stated preference survey is conducted to estimate the WTP to avoid accidents, the estimate will include all the components of the morbidity effects (see Box 7.4).

Box 7.4 Estimating Accident Reduction Benefits

The first step in estimating accident reduction benefits involves developing a reasonably accurate accident prediction model relevant for the project under consideration. This requires considerable data that allow an examination of the relationships between traffic volume, vehicle speed, design standards, terrain, non-motorized traffic, and accidents. If projections are made of accidents in the without-project case (allowing for any minor improvements or safety measures that might be introduced), these can then be compared with predictions in the with-project scenario allowing for growth in traffic and improvement in design.

Accident rates will typically be given per million vehicle-km travelled in a year. However, accidents will have varying degrees of severity and projections must be disaggregated to reflect this. A common distinction is between fatalities, serious injury, slight injury, and damage only where no injuries are involved. A prediction model may not be detailed enough to distinguish between these and if it is not then historical data on the respective share of accidents in the various categories can be applied. Estimation of the value of annual benefits from this source requires that accidents avoided in the different categories be multiplied by the monetary value placed on the different categories.

Accident costs can be specified in different ways. One approach distinguishes between direct costs (medical treatment, property damage, and administrative costs like legal and insurance fees), indirect costs (loss of future earnings for the individuals affected), and welfare costs (changes to the quality of life, covering both death and illness). In addition to accidents avoided, users will benefit from higher safety levels in terms of a lower risk of being involved in an accident. Direct costs are relatively straightforward in that they require basic data like average length of hospital stay and average cost per patient day, and average damage and administrative cost, with the average relating to whatever the accident categories are used in the prediction model. Average medical treatment costs must distinguish between in-patient care allowing for average length of stay (for serious injuries) and out-patient costs including average number of visits and average associated costs

continued on next page.

Box 7.4 continued.

(for slight injuries). Indirect costs are normally estimated as earnings foregone over the period the individual cannot work due to the accident; with fatalities this is lifetime earnings. Normally for simplicity, earnings foregone will be based on national average wages. Welfare costs reflect the pain, suffering, and loss of life incurred by those affected by an accident.

In principle, one can use a survey approach to try to elicit from respondents how much each transport user would be willing to pay to reduce the risk of an accident. This requires both information on how far accident probabilities are reduced by a new project and information on how much users are willing to pay to reduce these probabilities. This is a difficult concept to explain even in well-educated societies and there are serious practical problems in applying the contingent valuation methodology in this context. Furthermore, if used in conjunction with estimates of loss of output and cost of treatment, this approach will lead to double counting, since willingness to pay will capture both aspects. Hence, in relatively simple applications the expectation is that it will be the direct and indirect costs alone that will be estimated.

Source: World Bank (2005d).

The valuation of accident-related costs (for example, material damage to vehicles and road structures, legal costs, and use of emergency services) is normally by using data on replacement cost or actual expenditure. Estimation of these will require establishing a benchmark for average expenditures like medical bills and vehicle damage, and average loss of earnings for different accident categories. For example, distinctions have been drawn between accidents, “serious injury” (where hospital treatment is required), and “slight injury” (where no hospital treatment is required). The reliability of the cost estimates will inevitably be linked to the quality of the survey data. When accident reduction is a key objective of a project, serious efforts are necessary in estimating the number of accidents with and without the project and undertaking a detailed survey to establish relevant costs.

For projects with minor accident reduction benefits, approximate cost estimates using the “benefit transfer” approach are sometimes used. These appraisals use developed country estimates of mortality and morbidity costs.¹⁰ If WTP functions are available, these values can

¹⁰ For example, studies conducted in the European Union countries provide WTP to avoid fatalities and the direct and indirect costs of injury (HEATCO 2006, 87–9). The average for the Euro zone economies plus the UK gives values of €1.56 million per fatality, €0.214 million for severe injury, and €15,655 for slight injury at 2002 prices.

be transferred to developing countries using in-country data to estimate WTP. However, the direct transfer of benefits from developed countries to developing countries, with adjustment only for income differences, should be avoided in project appraisals as such transfers may result in large errors. A more acceptable approach would be to undertake a detailed in-country study and transfer the benefits within the country over time or regions for appraising transport projects.

D. Large Cost Reductions: Extension of Rule of Half

The valuation methods for VOC, time, and accident cost savings, together with the conventional rule of half, are applicable when cost savings are not very large. In this subsection, we describe a recent modification suggested for larger cost reductions. This involves: (i) identifying some additional points on the demand curve (three extra points are suggested for relatively large cost changes), (ii) joining these with a straight line, and (iii) calculating the area under each trapezium using the rule of half formula. In Figure 7.2, points a and e are the initial without- and with-project price–demand (cost–traffic) points, respectively. Three additional points: b, c, and d, are added using information on price elasticity, and points a to b, b to c, and so forth, are joined by a straight line. The areas for each trapezium can then be calculated by the rule of half. In Figure 7.2, the error that is avoided by this amendment to the simple rule of half is demarcated by the shaded area.¹¹

The difference between the two versions is illustrated numerically in Table 7.1. The original price–quantity points are $C_1 = 10$ and $T_1 = 100$, and price elasticity of demand is taken as -0.5 . A project is assumed to create a large price change of 40%, so $C_2 = 6$. Using the demand forecasting formula, assuming income is constant,

$$T_2 = T_1 * (C_2/C_1)^n \quad (5)$$

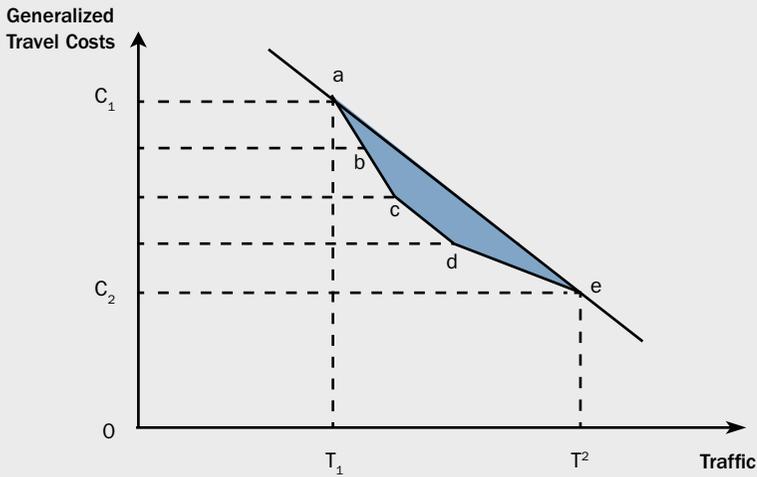
where T_2 is the new demand. Hence with these values,

$$T_2 = 100 * (6/10)^{-0.5} = 129.1$$

By the rule of half, total benefits are $(0.5 * 4) * (100 + 129.1) = 458.2$.

The same calculation is repeated for three additional VOC levels 9, 8, and 7 under the “numerical integration” approach.

¹¹ This modified approach is termed “numerical integration” and was put forward initially by Nellthorpe and Hyman (2001). It is summarized in World Bank (2005b).

Figure 7.2 Estimating Benefits through the Extended Rule of Half**Table 7.1 Illustration of Benefits for Total Traffic: Simple and Extended Rule of Half**

Vehicle Operating Costs (C)	Demand Growth ($n=-0.5$)	Demand (T)	Total Benefits
Simple Rule of Half			
10		100.0	
6	29.1%	129.1	458.2
Extended Rule of Half			
10		100.0	
9	5.4%	105.4	102.7
8	6.1%	111.8	108.6
7	6.9%	119.5	115.6
6	8.0%	129.1	124.3
			451.2

n = price elasticity of demand.

The difference between the simple and extended rule of half for total benefits is very small for a low price elasticity of demand (451.2 as opposed to 458.2 or 1.5%). The more responsive demand is to price (hence, the greater relative importance of generated traffic), the greater

the error will be from using the simple rule of half. The implication is that only if demand response to price is likely to be strong (at least -1.0), will the numerical integration approach be required. Therefore, even if the cost reductions are large, the appraisal can rely on the simple rule of half when there is credible evidence that price elasticity is small (see Table 7.2). It should be noted however, that the divergence between the results using the simple and extended approaches is considerably greater for the valuation of generated traffic rather than total traffic, so the more significant generated traffic is in total benefits, the greater the potential error from applying the simple rule of half.

Table 7.2 Difference between Benefits by Simple and Extended Approach

Assumed Price Elasticity	% Difference in Benefits between Simple and Extended Approach
-0.5	1.5
-1.0	4.0
-1.5	7.2
-2.0	11.0

E. Non-Marginal Changes: Modal Shifts and Rural Feeder Roads

The rule of half breaks down in cases where a project has a clear non-marginal impact by inducing new traffic that previously did not travel (such as a rural feeder road linking villages where previously access was not all-year round) or by creating a total modal shift (an urban light railway displacing bus services, for example). Such non-marginal changes cannot be addressed adequately in this approach, since a price–demand point for the without-project scenario will not exist as travel between any given set of origin and destination points without the project will either not occur (the feeder road case) or will occur on a different transport mode (the light railway case).

For projects that involve a modal shift, using the rule of half is not appropriate unless it can be reasonably assumed that the two modes are relatively close competitors, so that travel quality is the same, and hence the same demand function will be relevant. As modal shifts rarely involve this scenario, the most appropriate way of assessing benefits for this type of generated traffic is a form of stated preference survey that measures WTP for accessing the new service. For example, respondents can be

asked about their WTP for travel on an urban light railway instead of an existing bus service. This exercise is necessary anyway for planning the fare structure for the new project, and thus the results are relevant for both economic and financial calculations. The contingent valuation (CV) methodology to capture WTP, as set out in Chapter 4, can be adapted to survey transport users, particularly those faced with a modal switch.

Rural road projects in themselves are relatively low in capital cost and hence it is hard to justify utilizing substantial time and resources in benefit valuation. However, rural feeder roads increasingly have been added to large highway projects and, although a small share of costs, they are seen as contributing to a large proportion of the poverty reduction effect of the overall project; hence, the revival of interest in estimating their benefits and its distribution among villagers.

For rural feeder roads, the most acceptable approach is to estimate net income gains created by access allowed by a new project. This requires assessing the impact of road access controlling for as many other factors as possible that are likely to affect net incomes. One way of doing this is to survey similar villages in the project area, some of which do not have road access and some of which do. A regression model can be constructed that makes household income a function of household characteristics (like number of dependents, age and education of household head, number of animals, attendance at schools and clinics) and village characteristics (like distance from market, types of crops grown, and access to electricity and clean water) plus a dummy for all-season road access. The coefficient on the dummy will give a proxy measure of road impact per household controlling for all other factors. The average annual figures of incremental income increase due to road access can be summed over all households to give the project benefit from this “induced” effect. As an additional analysis, the confidence interval can be estimated and the lower and upper bounds of 95% confidence interval values can be used in the sensitivity analysis.

F. Terminal Value

The life of a transport project is closely related to issues of forecasting since typically some transport assets (like ports, quays, tunnels, and bridges) have relatively long lives. In principle, forecasts are required over a lengthy period that corresponds to the working life of the longest-lived assets. In practice, most ADB and World Bank road project appraisals,

for example, restrict the appraisal period to the economic life of the project (20 to 25 years) partly on the grounds that discounted values of costs and benefits become small after this. The uncertainty involved in predicting project parameters beyond this period is another reason for considering the economic life of the project in the appraisal. This procedure is acceptable provided that their terminal value is included as a benefit at the end of the appraisal period when the assets have a working life beyond the economic life of the project.

The residual accounting value of assets provides a first estimate of terminal value but it is unlikely to be very accurate due to the gap between book value and replacement value. In principle, estimating the terminal value requires forecasting since it will be determined by the discounted stream of future net benefits over the remaining working life of the asset. Hence, the terminal value (TV) of an asset is derived from the formula:

$$TV = \sum_{n=t+1..w} (B_n - C_n) / (1 + r)^n \quad (6)$$

where B and C are the future benefits and costs, respectively, created by the continued operation of the asset in year n, where the continued life of the asset runs from years t + 1 to w, where t is the end of the appraisal period, w is the last year of working life of the asset and r is the discount rate.

Terminal values are often omitted from the calculations on the grounds that when discounted at ADB's standard rate of 12%, a value in year 25 will be very low in present value terms. The argument is valid as a practical simplification for assets like bridges, tunnels, quays, and drainage systems. Where it becomes misleading, however, is when the terminal value is negative as a result of unmitigated environmental damage caused by a project and passed on to a future generation. Project design and planning normally aims to avoid long-term damage through preventive or mitigatory expenditure, but there can be significant unanticipated environmental damage (for example, major traffic congestion creating air pollution as a result of a poorly designed ring road) that create a significant negative terminal value.

Using a high discount rate is now viewed as a problematic procedure for long-term environmental issues. There is a serious debate on the appropriate long-run discount rate for environmental effects and there are theoretical grounds (for example, non-diminishing marginal utility derived from the environment as incomes rise) for the use of a low

rate for environmental effects.¹² The alternative to the use of a “special environmental discount” rate is to adjust relative values for a growing scarcity of environmental resources.

G. Environmental Effects

It is now recognized that all transport projects will have some environmental effects, which will vary from site to site. Some of the effects such as ecosystem fragmentation due to road construction should be identified in the environmental impact assessment (EIA) and mitigatory measures to remove the damage should be built into the project design and the cost of mitigation should be included in project costs. Where resettlement of affected communities is required, the costs of this will also be included in project costs. Transport projects will also contribute to atmospheric and noise pollution and, where possible, these effects should be valued and included in an appraisal. The current emphasis on global warming effects arising from CO₂ emissions and the perceived advantage of rail over road projects in this regard, suggest the importance of incorporating this effect in project appraisal. Insofar as fuel inputs are reduced for normal traffic, CO₂ emissions will be reduced, creating a benefit; but, for generated or additional traffic with extra fuel consumption there will be a negative effect with higher emissions, creating a project cost.¹³

The effects of air pollution arising from particulate matter and other chemicals, such as nitrogen oxides and sulphur dioxide, will vary with factors like location, population in the areas affected, prevailing wind direction, as well as the nature of the transport activity and the height of the emission source. Considerable work has been done in the European Union on costing these pollutants in terms of health damage costs, using the cost-of-illness, human capital, and stated preference survey approaches. Direct application of European values is considered inappropriate because these national average values per unit of pollutant are country- and situation-specific and also depend on income levels. Given the range of uncertainty in this form of environmental valuation it is adequate only to attempt to quantify air pollution costs for projects,

¹² See, for example, the theoretical discussion in pages 121–141 of Pearce et al. (2003), Stern (2008) and the simpler guidance in Curry and Weiss (2000). The *Green Book: Appraisal and Valuation in Central Government* (UK government HM Treasury 2003) now recommends a modestly declining discount rate over the medium term. The theoretical case for this is based on uncertainty. Also, see Chapter 3 on social discount rates.

¹³ Pearce, Atkinson, and Mourato (2006) have a very good survey of environmental economics as it relates to project appraisal.

where this is a major factor; for example, a mass transit rail link that will replace road traffic in congested urban areas. Research is ongoing into ways of quantifying and valuing CO₂ impacts in transport projects and can be applied in the Asian context.

7.1.4 Shadow Pricing

It has long been recognized that simple practical appraisal can be done in domestic price units (what is often called the domestic price level or numeraire) or in world price units (at the world price level or numeraire). The distinction is relevant whenever there are distortions in trade that create divergences between domestic and world prices. The average divergence is typically reflected in the standard conversion factor (SCF) or its inverse, the shadow exchange rate factor (SERF). Hence, an SCF of 0.9 implies that on average world prices are 10% below domestic prices or, alternatively, that domestic prices are 11.1% above world prices ($1/0.9 = 1.111$). Provided equivalent assumptions are made in both analyses, the economic internal rate of return (EIRR) will be the same whichever price level or unit is used.¹⁴

There can be different levels of disaggregation, but Table 7.3 shows a simple framework with the respective economic adjustments required for an appraisal using either the domestic or world price numeraire.

Table 7.3 Conversion Factor Framework for Appraisal of Transport Projects at the Domestic and World Price Numeraires

Primary Inputs	Conversion Factors (Domestic Price)	Conversion Factors (World Price)
Traded goods	SERF	1.0
Non-traded goods	1.0	SCF
Vehicle operator labor – work time	SWRF	SWRF * SCF
Vehicle operator labor – leisure time	1.0	SCF
Unskilled labor	SWRF	SWRF * SCF
Passengers – work time	SWRF	SWRF * SCF

continued on next page.

¹⁴ This equivalence is explained in Curry and Weiss (2000). ADB (2001, 94) discusses the issue briefly, pointing out that it is simpler to work in domestic prices. Fujimura and Weiss (2000) give a detailed exposition of the issues relating to distribution analysis from the perspective of appraisals by international agencies.

Table 7.3 continued.

Table 7.3 Conversion Factor Framework for Appraisal of Transport Projects at the Domestic and World Price Numeraires		
Primary Inputs	Conversion Factors (Domestic Price)	Conversion Factors (World Price)
Passengers – leisure time	1.0	SCF
Transfers – taxes/subsidies	0	0
SCF = standard conversion factor, SERF = shadow exchange rate factor, SWRF = shadow wage rate factor (which can vary by labor category).		

7.1.5 Developmental Benefits

It is sometimes argued that transport projects create benefits over and above those captured in the estimated value of normal and generated traffic. This could be through linkage effects that stimulate investment or production that would not have otherwise taken place. While such possibilities are always present, it should be noted that additional economic activity is stimulated by lower transport costs and including a separate category for developmental benefits risks double-counting. Therefore, a transport project will lead to increased travel of goods or people which in principle should already be picked up in estimates of generated traffic. Even where another mode of travel is involved (for example, extra rail freight created by a road), this additional travel creates an external benefit that should be included in an appraisal of the road. Thus in principle, the benefits of additional economic activity should be captured by the value of generated traffic.

The estimation of generated traffic is, however, not easy. The approach suggested here of using a price elasticity combined with the estimated change in generalized cost will not pick up structural changes in transport demand caused by additional investment or activity linked with the original project. It is only where there is strong evidence that a transport project stimulates other investment that would otherwise not be forthcoming, can development benefits be treated as a separate additional category. For example, an improved highway may pass by an existing industrial zone and provide an outlet for the goods produced there. If prior to the road improvement, enterprises were unwilling to locate there, increased activity in the zone stimulated by the transport project will generate more traffic. This will be in addition to the generated

traffic stimulated by the reduction in generalized cost created by the highway since the expansion of the zone represents a structural shift in supply conditions in the locality. In these circumstances, if the zone and the highway project are planned together, the most appropriate procedure is to include the costs and benefits from the zone in the economic appraisal of the highway. Where the zone is already constructed or under construction (so its costs are fixed and incurred anyway), the most appropriate procedure is to estimate the future traffic flow from the zone and treat this as additional generated traffic.

Examples of developmental benefits created by transport projects that do not lead to higher transport flows will be relatively rare. If additional economic developmental benefits of a transport project, on top of generated traffic estimates, are to be included in an economic analysis, it must be established that the additional economic activity would not otherwise take place and that it does not displace other equally valuable activity. Establishing these conditions is not easy and analysts should be very cautious about adding in additional developmental benefits. Under most circumstances, rather than resorting to vague arguments about linkage effects, it is preferable to base estimates of benefits on future traffic flows.

7.2 Transport Case Study

This case study is based on the Greater Mekong Subregion (GMS) Southern Coastal Corridor (SCC) Project for road improvement in Viet Nam and Cambodia (ADB 2007). The original appraisal has been modified in a number of ways to both strengthen the analysis and to simplify exposition. However, for realism, it retains the key parameters from the original appraisal as far as possible. The SCC project is an integral part of the larger Southern Economic Corridor, which is one of the strategic road links of the GMS running for 924 km from Bangkok across Cambodia to Nam Can in Viet Nam.

At the time of appraisal, commercial traffic could not use the border crossing between Cambodia and Viet Nam along the corridor as there was no formal customs facility, and segments of the road in Viet Nam and Cambodia offered limited accessibility due to poor road quality, narrow width, and inadequate bridges. The SCC project will improve

15 km of road in Cambodia (national highway NR33) and 96 km in Viet Nam (national highway QL80 and QL63), including the construction of two large bridges, and will create a new customs facility on the Cambodian side of the border at Preak Chak. Once the project is completed, it will allow a continuous flow of traffic along the full length of the road corridor and a border crossing for commercial traffic at Preak Chak in Cambodia and Xa Xia in Viet Nam. Total capital costs are estimated at \$172.79 million, of which more than 80% will be spent in Viet Nam and \$82 million will be financed by ADB.

In terms of the methodology, the case study extends standard practice in ADB appraisals in several ways:

- (i) It incorporates a price effect in traffic forecasts.
- (ii) It includes a separate estimate of developmental benefits based on future traffic.
- (iii) It shows a differential treatment of work and leisure time.
- (iv) It includes passenger as well as vehicle operator time savings and incorporates labor productivity increase in valuing time savings.
- (v) It incorporates a terminal value in assessing the economic viability of the project.

Since none of these effects are included in the original appraisal, parameter values have had to be assumed or taken from other studies.

7.2.1 Economic Rationale of the Project

The SCC is 1 of 10 high priority subregional road projects identified in a Subregional Transport Sector Study completed in 1994 to facilitate cross-border trade and support economic development in the GMS countries. Regional cooperation and integration in the transport sector has been given high priority in the GMS because the poor state of transport infrastructure is a major constraint to intra-regional trade and economic growth. Evidence also shows that the poor transport system restricts access to job opportunities, markets, education, and health facilities in the GMS. Therefore, improving roads in areas where the population currently does not have good access is expected to have a major positive impact on livelihoods. Although sections of the SCC in Thailand and

Cambodia are in good condition, the highway is incomplete in Cambodia, and much of the Vietnamese section requires major rehabilitation and improvement. By reducing travel time and VOCs along the SCC, the project will encourage economic activity in the affected provinces, provide employment opportunities for the local population, and improve access to social services. At the national level, the project responds to the emphasis given by both governments to improve the road network for enhancing economic growth and poverty reduction.

The agencies responsible for project implementation are public sector bodies: the Viet Nam Roads Administration and the Government of Cambodia Ministry of Public Works and Transport. The private sector might have been involved through build-operate-transfer schemes, but in the current context of Viet Nam this option had yet to be explored and no private firms had expressed an interest in playing such a role. Therefore, the judgment in the original appraisal was that public sector investment in the project does not crowd out potential private sector involvement.

The project is designed to enhance cross-border facilities at the borders between Cambodia and Thailand at Koh Kong, and between Cambodia and Thailand at Preak Chak–Xa Xia and to provide capacity building support to the two governments to address coordination failures between them and to ensure adequate road maintenance is carried out.

Although the project covers two GMS countries, for the purpose of the appraisal, the project is treated as a single project in the economic analysis using the approach of the original analysis.¹⁵ Hence, no attempt is made to disaggregate benefits and costs between the two countries and the economic analysis calculates the total return to the project that will accrue to both economies, although the expectation is that the bulk of this will go to Viet Nam.

7.2.2 Project Alternatives and Least-Cost Option

In principle, roads are not the only transport mode over the distance covered by the project. However, neither improved rail nor water links provide a viable alternative. Rail connections are not well developed and a rail alternative between the Cambodian border and either Nam Can or

¹⁵ Application of the methodology for distributing benefits between two countries is illustrated in Chapter 9 for an electricity generation project.

Ca Mau in Viet Nam would involve very heavy capital investment in new track that would not be economically viable at current and projected levels of traffic. At present, water transport is the main alternative mode to the road improvement. However, goods movement by water is slow and carrying capacity is limited. Initial approximate calculations suggest that the full benefits of intra-GMS trade along the corridor cannot be achieved with continued heavy use of water transport and that improvement to the current road network offers considerably higher returns.

Initial project screening requires a basic cost-effectiveness calculation to ensure that the most efficient alternative option has been selected for detailed appraisal. In this project the alternatives considered were three slightly different routes based on similar road surfaces that link Kampong Trach in Cambodia to Ca Mau in Viet Nam. On the Cambodian side, the route from Kampong Trach to the border crossing at Preak Chak is common to each alternative with the choice between three routes within Viet Nam from the crossing point on the Vietnamese side at Xa Xia to Ca Mau. The three options had slightly different road lengths with option 2 being slightly more direct in its connection between the center of Ca Mau city, the nearby industrial zone Khanh An, and the start of the route northwards to Cambodia. The estimated capital costs of options 1 and 2 were similar, with the latter expected to generate slightly higher traffic and cost savings because of its more direct links. Option 3 was slightly longer and involved heavier capital costs because the widening of the road along part of the route would necessitate significantly more resettlement than that for the other alternatives. Table 7.4 summarizes the cost-effectiveness calculations, which used financial costs since a detailed disaggregation of cost categories to allow economic adjustments was not available. However, they incorporate estimates of resettlement costs and approximate estimates of all necessary mitigatory environmental expenditure.

Table 7.4 Results of Least-Cost Analysis

Option	Distance (km)	Present Value of Capital	
		Costs ^a (\$ million)	Cost/km (\$ million)
1	220	155	0.70
2	214	145	0.68
3	225	189	0.84

km = kilometer

^aDiscounted at 12%.

Source: ADB (2007).

Option 2 was marginally the cheaper option and, as the more direct route, offered greater potential for traffic-related benefits. It was therefore the alternative selected for detailed appraisal.

7.2.3 Forecast Traffic

For the detailed appraisal, the full project road was divided into five sections, with the first section being the 15 km in Cambodia to the border crossing, and the other four covering the 96 km of road in Viet Nam. Traffic counts and origin–destination surveys were conducted on each section of the road over 2 days and the hourly and daily figures were adjusted for seasonal factors to give annual average daily traffic by vehicle type. The origin–destination survey also collected information on numbers of passengers, and the use of vehicles for freight movements. The survey results for the pre-project situation are presented in Table 7.5 using six categories of motor vehicles and a general category for non-motorized transport.

Table 7.5 Existing Road Use: AADT by Vehicle Type

Section (km)	Cars/Jeeps	Light Trucks	Medium Trucks	Heavy Trucks	Buses	Motorcycles	Non-motorized
1 (15)	95	35	35	15	30	2095	400
2 (22)	975	540	535	219	142	1573	53
3 (36)	920	605	617	466	164	7443	54
4 (26)	420	115	95	140	66	5134	20
5 (12)	150	220	120	95	80	2790	43

AADT = annual average daily traffic, km = kilometer.

Source: ADB (2007).

Road use was uneven and initially was dominated by scooter and motorcycle traffic with significant use of carts and bicycles on the Cambodian side (section 1). The project included road widening on some stretches and this was expected to encourage considerably more use by heavier motorized vehicles. Average length of journey for the different sections and vehicle types is given in Table 7.6.

Table 7.6 Average Journey Length (km)

Section (km)	Cars/Jeeps	Light Trucks	Medium Trucks	Heavy Trucks	Buses	Motor-cycles	Non-motorized
1 (15)	14	8	12	15	15	9	6
2 (22)	15	18	20	19	17	12	5
3 (36)	22	29	32	35	32	9	4
4 (26)	12	24	23	25	18	8	4
5 (12)	7	9	10	10	11	6	3

km = kilometer
Source: ADB (2007).

Multiplying the respective AADT in Table 7.5 by the corresponding average journey lengths by section and type of vehicle in Table 7.6 gives vehicle-km in the baseline case (2008). For example, road section 1 will have 1,330 (= 95 * 14) vehicle-km of cars/jeeps in 2008. The vehicle-km for each road section are then summed to get the total vehicle-km by type of vehicle (see Table 7.7).

Table 7.7 Estimated Daily and Annual Traffic by Vehicle Type, 2008

Section (km)	Cars/Jeeps	Light Trucks	Medium Trucks	Heavy Trucks	Buses	Motor-cycles	Non-motorized
1 (15)	1,330	280	420	225	450	18,855	2,400
2 (22)	14,625	9,720	10,700	4,161	2,414	18,876	265
3 (36)	20,240	17,545	19,744	16,310	5,248	66,987	216
4 (26)	5,040	2,760	2,185	3,500	1,188	41,072	80
5 (12)	1,050	1,980	1,200	950	880	16,740	129
Total daily vehicle-km	42,285	32,285	34,249	25,146	10,180	162,530	3,090
Total annual vehicle-km	15,434,025	11,784,025	12,500,885	9,178,290	3,715,700	59,323,450	1,127,850

km = kilometers.
Source: ADB (2007).

Traffic projections in the original appraisal were based on assumed income elasticities of demand by different types of vehicle and growth

projections for income in the provinces through which the road passes. However it is also necessary to allow for: (i) the decline in normal traffic in the without-project scenario due to congestion on the road, and (ii) the impact of cost reductions created by the project in stimulating new road use. Use of the elasticity formula given in Section 7.1.2 allows the combination of these effects to be incorporated. It is assumed that as road speeds increase and incomes rise, non-motorized traffic will decline over time. As the benefits from surface improvement and road widening will be of only minor consequence for non-motorized traffic, it is omitted from the calculations.

Total traffic growth on the road is given by the interaction between income and price elasticities. Strictly, elasticities will vary by vehicle type, journey purpose, and time of day. Approximate estimates for the region suggest income elasticity figures of 2.0 for motorcycles, 1.2 for cars/jeeps, and 1.1 for buses and trucks. However, the high elasticity of 2.0 for motorcycles is assumed to decline over time as ownership of motorcycles spreads; to allow for this, a lower figure of 1.5 is used after 2018. Provincial income growth is also uncertain but the continuation of past trends implies a minimum of at least 6% annually. Price effects on demand will depend on the scale of VOC savings and the assumed price elasticity.

VOC reductions are calculated using the HDM-4 model. This requires specifying a surface roughness level or International Roughness Index (IRI) with and without the project, projected vehicle speeds, and country-specific price data. Table 7.8 summarizes the estimated VOC reductions (\$ per vehicle-km) by vehicle type derived for this project from the HDM-4 model. The cost of the time of drivers, but not passengers, is included in VOC. The proportionate cost reductions (including the cost of time) are used in conjunction with a price elasticity of -0.5 and an assumed congestion factor of 5% after 10 years.

Total traffic must be decomposed into normal and generated traffic because of the different basis for valuation. The difference between total traffic growth and normal traffic growth can be used as a proxy for generated traffic.

The demand factor (DF) used to convert traffic for vehicle type x in year 0 to a projection in year t is:

$$DF_{xt+1} = (1+g_t)^y * (C_{xt}/C_{x0})^n \quad (7)$$

Table 7.8 Vehicle Operating Costs with and without the Project, \$/km

Vehicle Type	Without-project (IRI = 6)	With-project (IRI = 2)	VOC Savings	VOC Ratio	% Cost Reduction
Cars/Jeeps	0.42	0.15	0.27	0.36	64
Light Truck	0.21	0.12	0.09	0.57	43
Medium Truck	0.33	0.20	0.13	0.61	39
Heavy Truck	0.64	0.37	0.27	0.58	42
Bus	0.52	0.30	0.22	0.58	42
Motorcycles	0.04	0.03	0.01	0.75	25

IRI = international roughness index, km = kilometer, VOC = vehicle operating costs.
Source: ADB (2007).

that is, the change in income between the two years raised to the power y (where y is the income elasticity of demand) multiplied by the change in generalized cost between the two years raised to the power n (where n is the price elasticity of demand). To illustrate for cars/jeeps, the cost reduction created when the road improvement is fully operational in 2011 is 64% (from Table 6.9), so the demand factor is $(1.06)^{1.2} \cdot (0.36)^{-0.5}$ which gives 1.795. However, the cost reduction is a once-for-all event and after 2011 the demand factor reduces to $(1.06)^{1.2} \cdot (1.0)^{-0.5}$ which is 1.072.¹⁶ Table 7.10 gives a time-slice of the demand factors to 2013 by vehicle type.

Table 7.9 Demand Factors by Vehicle Type

Year	Cars/ Jeeps	Light Trucks	Medium Trucks	Heavy Trucks	Buses	Motor- cycles
2008	1.000	1.000	1.000	1.000	1.000	1.000
2009	1.072	1.066	1.066	1.066	1.066	1.124
2010	1.072	1.066	1.066	1.066	1.066	1.124
2011	1.795	1.410	1.370	1.402	1.404	1.297
2012	1.072	1.066	1.066	1.066	1.066	1.124
2013	1.072	1.066	1.066	1.066	1.066	1.124

¹⁶ Note that the traffic counts were made in 2008 and the project construction was assumed to be completed by end of 2010. Therefore the price effect was assumed to occur in 2011. Because of the price effect the traffic flow will increase significantly. In this case because the improved road segment is a part of the regional road corridor, such a jump is feasible. If such a big jump is not feasible the price effect could be spread over several years.

Total traffic in year $t+1$ (T_{xt+1}) will be the previous year's traffic (T_{xt}) multiplied by DF_{t+1} .

$$T_{xt+1} = T_{xt} * DF_{xt+1} \quad (8)$$

The next step is to multiply the vehicle-km starting from the baseline case of 2008 (from Table 7.7) by demand factors (from Table 7.9) to arrive at projected vehicle-km by vehicle type per year (Table 7.10). On the assumption that average journey lengths remain constant, future vehicle-km multiplied by journey length gives future vehicle-km by different types of vehicle. As costs per vehicle are estimated per km, total vehicle-km are required to estimate gross benefits.

Application of demand factors to traffic starting in the base year gives projected total traffic volume. To illustrate for cars/jeeps, there will be 16.55 million vehicle-km in 2009, which is obtained by multiplying 15.43 million vehicle-km in 2008 with the demand factor of 1.072. With the once-for-all effect of cost reduction in 2011, the previous year's traffic of 17.75 vehicle-km multiplied by the demand factor of 1.795 gives a projected traffic figure of 31.85 vehicle-km in 2011.

Table 7.10 A Slice of Projected Total Traffic (2009–2013), million vehicle-km

Year	Cars/ Jeeps	Light trucks	Medium trucks	Heavy trucks	Buses	Motor cycles
2008	15.43	11.78	12.50	9.18	3.72	59.32
2009	16.55	12.56	13.33	9.79	3.96	66.66
2010	17.75	13.40	14.21	10.43	4.22	74.89
2011	31.85	18.89	19.46	14.63	5.93	97.17
2012	34.16	20.14	20.75	15.60	6.32	109.18
2013	36.63	21.48	22.12	16.63	6.74	122.67

km = kilometer.

Normal traffic is the traffic flow that would have occurred without the project. This can be estimated using income elasticity of demand with an adjustment for reduction in traffic flow due to congestion without the project. The demand factor for normal traffic is the product of the expected change in income raised to the power y and the rate of decline caused by congestion and inadequate maintenance levels in the without-project scenario. Hence for year $t + 1$, normal traffic (NT) is:

$$NT_{xt+1} = NT_{xt} * ((1+g)^y)^*a \quad (9)$$

where a is an adjustment factor ($a < 1$) to allow for the impact of congestion.

Normal traffic is estimated using income elasticities only, since without the project there will be no reduction in the cost of travel. VOC may increase as road conditions further deteriorate without the project. However, it is difficult to predict future VOC, and the adjustment factor for increased congestion on the unimproved road partly takes into account this possible increase. In this case, a congestion factor of 0.95 is applied to the demand factor from 2019 onwards. Hence for cars/jeeps, the normal demand factor each year is $(1.06)^{1.2}$ which gives 1.072; from 2019 onwards the impact of congestion starts to operate and the demand factor becomes 1.072×0.95 , which is 1.019. Demand factors for all vehicle types are scaled down by multiplication by 0.95 from 2019.

Generated traffic (GT) is the difference between total projected traffic and normal traffic. As a result of the slower growth of normal traffic due to congestion in the without-project case by the end of the period of analysis, generated traffic dominates normal traffic.

$$GT_{xt+1} = T_{xt+1} - NT_{xt+1} \quad (10)$$

This approach assumes that the project has no impact on per capita income growth, but that it affects only the generalized cost of travel. Also, it cannot distinguish between traffic diverted from another mode—as a result of the change in generalized cost—and genuinely new journeys, with both valued at half VOC savings as a proxy for user WTP.

7.2.4 Developmental Effect

In addition to these traffic projections based on income and price elasticities, the road improvement enhances accessibility to an existing industrial zone, the Khanh An zone, located 9 km north west of Ca Mau city. At the time the project was planned, the zone was already under construction with its investment a fixed cost. However, completion of the road project will serve as an incentive for new enterprises to start operations in the zone since most of its freight traffic will be expected to go to Ho Chi Minh City along sections two and three of the road for about 50 km before turning off. This will be additional traffic not reflected in the projections based on income and price effects.

Based on likely new investments covering 50 hectares of land and from experience in other zones in Viet Nam, it is estimated that as much as 300 extra truck movements per day by 2020 will be generated. These will not start immediately and the analysis here assumes a phased build-up, starting from an extra 50 trucks in 2011, reaching an extra 300 by 2020 and stabilizing at this level up to 2030. Assuming 300 working days per year and an average use of 50 km, this gives an extra traffic flow of 4.5 million vehicle-km by 2020. These trucks are assumed to be split evenly between medium and heavy trucks. It is assumed that no extra investment in factory space will be required to allow this higher truck flow, given existing unutilized capacity (although if it were needed the cost of this extra factory space should be included as part of total project costs). These additional truck flows are included as part of generated traffic and are valued in the same way as other generated traffic.

7.2.5 Project Benefits and Costs

The original economic appraisal for the project uses the world price numeraire (and takes US dollars as the currency unit), which appears a common practice for ADB transport projects. The choice of currency unit per se is unimportant and for this case study, the appraisal has been reworked in the domestic price numeraire, although for comparability world price results are also given.

Project benefits include:

- (i) VOC savings for normal traffic,
- (ii) WTP for travel by generated traffic (approximated by half VOC savings),
- (iii) WTP for generated industrial zone traffic (approximated by half VOC savings),
- (iv) passenger time savings from normal traffic and generated traffic (differentiated between work time and leisure time),
- (v) savings in the minimum level of maintenance expenditure that would have been incurred on the road without the project, and
- (vi) project terminal value.

Project costs consist of:

- (i) capital costs of the road improvement, including resettlement costs; and
- (ii) maintenance expenditure for the improved road.

Road improvements in some instances create benefits in lower accident rates, but as this project will increase traffic flow there is the risk of higher (rather than lower) accident rates and this is a cost for the economic appraisal. However, for purposes of this case study, accident costs are not included.¹⁷ VOC savings by vehicle type in Table 7.8 are at constant financial prices and include valuations of driver time using the average wage in the Mekong Delta region of \$59 per month (derived as 85% of the national average for Viet Nam). Assuming 180 working hours per month gives a cost of time of \$0.33 per hour. This is assumed to include any overhead charges relevant to the cost of employment. This is the wage used to derive the VOC estimates in Table 7.8. Passenger time is excluded from the VOC. The origin–destination survey throws some light on the number of vehicle occupants, but there is insufficient data for a precise breakdown between operators and passengers. From the survey, the ratio of total occupants to drivers is on average 2.0:1.0 for cars/jeeps, 1.5:1.0 for motorcycles, 1.3:1.0 for all categories of truck, and 25:1 for buses. Again drawing on the survey, for cars/jeeps and motorcycles it is assumed that all passenger time is for leisure, while for buses and trucks, the shares are 40% and 20%, respectively.

The value of leisure time is taken as 30% of the value of work time. As noted above, the wage rate—the basis for valuation of work time—will be determined by labor productivity, which will be rising over the life of the project. An annual average growth of labor productivity of 3% is assumed, so that real wage is increased at 3% annually. In addition to valuing time savings, this adjustment is applied to the costs of vehicle operators and vehicle maintenance personnel. It is not applied to labor used for road maintenance which is treated as wholly unskilled with a constant real wage.

For economic appraisal, VOC savings at financial prices need to be converted to economic prices. This requires decomposing the different benefit and cost categories into tradables, nontradables, labor, and transfers. As the analysis is carried out using domestic price units the

¹⁷ As discussed in Section 7.1.3, the most readily available valuation method - the benefit transfer approach using scaled European values - is not good practice and can give dubious results.

appropriate conversion factors are the SERF of 1.111 for tradables, 1 for nontradables, a shadow wage rate factor (taken to be 0.75 for all types of work time and 1 for leisure) and zero for transfers. For passenger time, the national average wage is used for work time and 30% of this for leisure time. The framework used here is set out in Table 7.11.

Table 7.11 Primary Inputs and Conversion factors

Primary Inputs	Conversion Factors (Domestic Price Numeraire)
Tradables	SERF = 1.111
Nontradables	1
Vehicle operator labor – work time	$(SWRF * \text{operator wage}) = (0.75 * \text{wage})$
Vehicle operator labor – leisure time	$(0.3 * \text{operator wage}) = (0.3 * \text{wage})$
Unskilled labor	$(SWRF * \text{unskilled wage}) = (0.75 * \text{wage})$
Passengers – work time	$(SWRF * \text{average wage}) = (0.75 * \text{wage})$
Passengers – leisure time	$(0.3 * \text{average wage}) = (0.3 * \text{wage})$
Transfers – taxes/subsidies	0

SERF = shadow exchange rate factor, SWRF = shadow wage rate factor.
Source: ADB (2007).

The breakdown of VOC savings and road maintenance expenditure savings into various primary input categories is shown in Table 7.12.

Table 7.12 VOC Savings and Road Maintenance by Input Category (%)

Input	VOC Savings				
	Fuel	Tires	Vehicle Maintenance	Time	Road Maintenance
Tradables	80	90	0	0	0
Nontradables	7	10	50	0	50
Labor	0	0	50	100	45
Transfers	13	0	0	0	5
Total	100	100	100	100	100

VOC = vehicle operating cost.
Source: ADB (2007).

Vehicle operator time savings are already included in estimates of VOC savings and hence cannot be included twice. Passenger time savings

for normal traffic are shown as a separate benefit and are divided between work and leisure time. Savings in passenger work time for normal traffic is adjusted by the shadow wage rate factor (SWRF) of 0.75; no conversion factor is applied for leisure time. WTP is by definition at domestic prices and reflects nontraded value. Therefore the half of VOC savings used as a proxy for WTP in the valuation of generated traffic is unadjusted from the financial price data (with a conversion factor of 1.0). Passenger time savings for generated traffic are a component of WTP for additional traffic flows. The project implementation period was considered to be 3 years beginning in 2008. A 20-year project life (from 2011 to 2030) was assumed. However, the road can be used beyond this period up to 2040. The project's terminal value was estimated using the general formula for the terminal value (TV) of an asset:

$$TV = \sum_{n=t+1...w} (B_n - C_n) / (1 + r)^n \quad (11)$$

where B and C are the future benefits and costs, respectively, created by the continued operation of the asset in year n, where the continued life of the asset runs from years t + 1 to w, where t is the end of the appraisal period, w is the last year of working life of the asset, and r is the discount rate.

In applying this formula, it is assumed that because of the rising congestion on the road beyond 2030, the final year net benefits of the project are reduced by 10% each year from 2030 to 2040. This gives a terminal value of \$242.74 million in 2030, which in present value terms reduces to \$20.06 million.

7.2.6 Cost–Benefit Analysis

Table 7.13 gives the present values of all items at financial prices and at economic prices. The economic prices are shown in both world and domestic price numeraire. The economic prices are directly comparable, with the domestic price values higher than world price values by the SERF. Hence, for example, VOC savings for cars/jeeps in economic prices at the domestic price level is:

$$22.35 * 1.111 + 8.42 * 1.0 + 10.9 * 0.75 + 3.24 * 0 = 41.43$$

The equivalent calculation in world prices is:

$$22.35 * 1 + 8.42 * 0.9 + 10.9 * 0.75 * 0.9 + 3.24 * 0 = 37.28$$

These results are directly equivalent as $41.43/37.28 = 1.111$, which is the average ratio of domestic to world prices or $1/SCF$.

The results show the project has an EIRR of 17.3% at either numeraire, and an NPV at domestic prices of \$66.96 million. The equivalent value at the world price level is lower by 11% at \$60.26 million. Table 7.14 summarizes the benefits and costs in an economic resource statement at the domestic price numeraire.

Table 7.13 Economic Appraisal at the World and Domestic Price Numeraire Present Values at 12% (\$ million)

	Costs and Benefits in Financial Prices						Economic Prices	
	Financial Prices	Tradables	Non-Tradables	Labor		Taxes	World	Domestic
				Work	Leisure			
Adjustment Factors				SWRF*				
			SCF	SCF	SCF			
World Price		1	0.90	0.675	0.90	0		
Domestic Price		SERF		SWRF				
		1.111	1	0.750	1	0		
BENEFITS								
Normal Traffic: VOC Savings								
Cars/Jeeps	44.91	22.35	8.42	10.90	0.00	3.24	37.28	41.43
Light trucks	11.33	5.71	1.09	3.75	0.00	0.78	9.23	10.25
Medium trucks	18.30	6.93	1.20	9.03	0.00	1.15	14.10	15.66
Heavy trucks	25.83	16.26	1.88	5.39	0.00	2.30	21.59	23.99
Buses	8.35	4.19	1.47	2.10	0.00	0.59	6.93	7.71
Motorcycles	10.59	4.63	0.68	4.44	0.00	0.63	8.43	9.36
Generated Traffic: WTP								
Cars/Jeeps	20.62		20.62				18.56	20.62
Light trucks	2.93		2.93				2.63	2.93
Medium trucks	5.11		5.11				4.60	5.11
Heavy trucks	7.88		7.88				7.09	7.88
Buses	2.10		2.10				1.89	2.10
Motorcycles	1.82		1.82				1.64	1.82
Passenger Time: Normal Traffic								
Cars/Jeeps	1.33			0.00	1.33		1.19	1.33
Light trucks	0.82			0.76	0.06		0.56	0.63

continued on next page.

Table 7.13 continued.

	Costs and Benefits in Financial Prices					Economic Prices		
	Financial Prices	Tradables	Non-Tradables	Labor		Taxes	World	Domestic
				Work	Leisure			
Adjustment Factors				SWRF*				
World Price		1	0.90	0.675	0.90	0		
Domestic Price		SERF 1.111	1	SWRF 0.750	1	0		
Medium trucks	2.17			2.02	0.16		1.50	1.66
Heavy trucks	1.27			1.19	0.09		0.88	0.98
Buses	17.27			14.39	2.66		12.31	13.67
Motorcycles	0.60			0.00	0.60		0.54	0.60
Passenger Time: Generated Traffic								
Cars/Jeeps	0.64			0.00	0.64		0.58	0.64
Light trucks	0.22			0.21	0.02		0.15	0.17
Medium trucks	0.63			0.59	0.04		0.44	0.48
Heavy trucks	0.41			0.38	0.03		0.28	0.32
Buses	4.67			3.89	0.76		3.33	3.70
Motorcycles	0.11			0.00	0.11		0.10	0.11
Maintenance savings	0.96		0.48	0.43		0.05	0.72	0.80
Terminal value	20.06		20.06				18.05	20.06
Total Benefits	210.93						174.60	194.00
COSTS								
Capital	139.72	13.97	76.85	41.92		6.99	111.43	123.81
Road Maintenance	3.86	0.00	1.93	1.74		0.19	2.91	3.23
Total Costs	143.58						114.33	127.04
NPV	67.35						60.26	66.96
IRR	17.3%						17.3%	17.3%

IRR = internal rate of return, NPV = net present value, SCF = standard conversion factor, SERF = shadow exchange rate factor, SWRF = shadow wage rate factor, VOC = vehicle operating cost, WTP = willingness to pay.
Source: ADB (2007).

Table 7.14 Economic Resource Flow, \$ million (Domestic Price Numeraire)

	Benefits						Costs			
	VOC Savings		Passenger Time Savings	Savings in Maintenance	Terminal Value	Total Benefits	Capital	Road Maintenance	Total Costs	Net Benefits
	Normal	Generated								
2009	0	0	0	0	0	0	60.80	0.00	60.80	-60.80
2010	0	0	0	0	0	0	44.68	0.00	44.68	-44.68
2011	12.31	3.026	2.145	0	0	17.48	47.63	0.00	47.63	-30.15
2012	13.25	3.404	2.367	0.084	0	19.11		0.06	0.06	19.05
2013	14.28	3.678	2.604	0.042	0	20.60		0.03	0.03	20.58
2014	15.39	3.971	2.865	0	0	22.22		0.11	0.11	22.11
2015	16.59	4.285	3.153	0	0	24.02		0.16	0.16	23.87
2016	17.89	4.622	3.469	0	0	25.98		2.10	2.10	23.87
2017	19.29	4.984	3.817	0	0	28.09		0.15	0.15	27.94
2018	20.82	5.338	4.199	0	0	30.35		2.29	2.29	28.07
2019	21.29	6.364	4.518	0	0	32.17		0.18	0.18	31.99
2020	21.78	7.466	4.864	2.563	0	36.67		0.71	0.71	35.96
2021	22.28	8.651	5.238	0	0	36.17		0.12	0.12	36.05
2022	22.80	9.946	5.645	0	0	38.39		2.17	2.17	36.22
2023	23.33	11.359	6.088	0	0	40.78		0.13	0.13	40.65
2024	23.88	12.901	6.570	0.419	0	43.77		0.21	0.21	43.56
2025	24.45	14.582	7.094	0	0	46.13		0.23	0.23	45.89
2026	25.04	16.417	7.664	0	0	49.12		2.60	2.60	46.52
2027	25.65	16.416	8.286	0	0	52.35		0.24	0.24	52.11
2028	26.27	20.597	8.964	0	0	55.83		1.52	1.52	54.31
2029	26.92	22.973	9.702	0	0	59.60		0.25	0.25	59.35
2030	27.59	25.563	10.508	0	242.74	306.40		0.84	0.84	305.57
NPV	108.39	40.45	24.29	0.80	20.06	194.00	123.81	3.23	127.04	66.96
IRR										17.3%

IRR = internal rate of return, NPV = net present value, VOC = vehicle operating cost.
Source: ADB (2007).

7.2.7 Distribution and Poverty Analysis

The direct gains from the project are distributed between:

- (i) vehicle operators,
- (ii) passengers,
- (iii) workers (as vehicle operators or construction laborers), and
- (iv) government.

Vehicle operators gain the savings in VOC at financial prices (since these are the prices they must pay) which total \$159.77 million in present value terms and cover both normal and generated traffic (see Tables 7.15 and 7.16). Passengers gain savings in both work and leisure time. However working time is less valuable in economic terms than at financial prices because of the labor conversion factor reflecting an opportunity cost of labor 75% of the wage. This reduction in the value of working passenger time is shown as a loss. For example, bus passengers gain \$14.39 million from time savings for normal traffic, when time is valued at the market wage paid. However, as the economic value of working time is assumed to be 75% of this, \$3.6 million or 25% is deducted. The workers group refers to vehicle operators and those employed in the construction of the road. Vehicle operators lose because the labor time required by normal traffic is reduced. They lose the difference between the wage paid and what they are assumed to be able to earn elsewhere (25% of the total wage at financial prices which is \$8.9 million). On the other hand, workers employed in the construction of the project gain \$10.81 million, or 25% of the wage paid. This is the net figure after allowing for the savings in labor cost on maintaining the road without the project.

Table 7.15 Distribution Analysis (\$ million, Domestic Price Numeraire)

Adjustment Factor	Financial Present Values	Gain/Loss				Total Gains	Economic Present Values
		Labor		Government			
		Work	Leisure	Tax	Forex premium		
		SWRF-1	CF-1	CF - 1	SERF-1		
		-0.25	0	-1	0.11		
BENEFITS							
Normal Traffic: VOC Savings							
Cars/Jeeps	44.91	-2.73	0.00	-3.24	2.48	-3.48	41.43
Light trucks	11.33	-0.94	0.00	-0.78	0.63	-1.08	10.25

continued on next page.

Table 7.15 continued.

Table 7.15 Distribution Analysis (\$ million, Domestic Price Numeraire)							
Adjustment Factor	Financial Present Values	Gain/Loss				Total Gains	Economic Present Values
		Labor		Government			
		Work	Leisure	Tax	Forex premium		
		SWRF-1 -0.25	CF-1 0	CF - 1 -1	SERF-1 0.11		
Medium trucks	18.30	-2.26	0.00	.1.15	0.77	-2.64	15.66
Heavy trucks	25.83	-1.35	0.00	-2.30	1.81	-1.84	23.99
Buses	8.36	-0.53	0.00	-0.59	0.47	-0.65	7.71
Motorcycles	10.59	-1.11	0.00	-0.63	0.51	-1.23	9.36
Generated Traffic: WTP							
Cars/Jeeps	20.62					0.00	20.62
Light trucks	2.93					0.00	2.93
Medium trucks	5.11					0.00	5.11
Heavy trucks	7.88					0.00	7.88
Buses	2.10					0.00	2.10
Motorcycles	1.82					0.00	1.82
Passenger Time: Normal Traffic							
Normal/VOC		Work	Leisure				
Cars/Jeeps	0.00	1.33	0.00	0.00		0.00	1.33
Light trucks	0.76	0.06	-0.19	0.00		-0.19	0.63
Medium trucks	2.02	0.15	-0.50	0.00		-0.50	1.66
Heavy trucks	1.19	0.09	-0.30	0.00		-0.30	0.98
Buses	14.39	2.88	-3.60	0.00		-3.80	13.67
Motorcycles	0.00	0.60	0.00	0.00		0.00	0.60
Passenger Time: Generated Traffic							
		Work	Leisure				
Cars/Jeeps	0.00	0.64	0.00	0.00		0.00	0.64
Light trucks	0.21	0.02	-0.05	0.00		-0.05	0.17
Medium trucks	0.59	0.04	-0.15	0.00		-0.15	0.48
Heavy trucks	0.38	0.03	-0.10	0.00		-0.10	0.32

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Table 7.15 continued.

Table 7.15 Distribution Analysis (\$ million, Domestic Price Numeraire)								
Adjustment Factor	Financial Present Values		Gain/Loss				Economic Present Values	
			Labor		Government			
	Work	Leisure	Tax	Forex premium	Total Gains			
			SWRF-1 -0.25	CF-1 0	CF - 1 -1	SERF-1 0.11		
Buses	3.89	0.78	-0.97	0.00			-0.97	3.70
Motorcycles	0.00	0.11	0.00	0.00			0.00	0.11
Maintenance savings	0.96		-0.11		-0.05	0.00	-0.16	0.80
Terminal value	20.06		0.00		0.00	0.00	0.00	20.06
Total Benefits	210.93		-14.87		-8.74	6.67	-16.93	194.00
COSTS								
Capital	139.72		-10.48		-6.99	1.55	-15.91	123.81
Maintenance	3.86		-0.43		-0.19	0.00	-0.63	3.23
Total Costs	143.58		-10.91	0.00	-7.18	1.55	-16.54	127.04
Net Benefits	67.35		-3.96	0.00	-1.56	5.12	-0.39	66.96
CF = conversion factor, SERF = shadow exchange rate factor, SWRF = shadow wage rate factor, VOC = vehicle operating cost, WTP = willingness to pay. Source: ADB (2007).								

The government is affected in several ways: it funds the project and meets all capital and maintenance costs at financial prices, saves maintenance costs in the without-project scenario, and gains the terminal value. This gives a net figure of \$122.56 million. It loses direct tax revenue due to the reduced VOC, but on the other hand there is an extra foreign exchange expenditure as a result of the project. The shadow exchange rate (SER) is 11% above the market rate, which is taken to be due to trade taxes. Hence 11% of the extra foreign exchange expenditure or \$5.12 million is treated as a gain to the government. This gives a net loss of \$119 million.

Hence, as there are no toll charges in the project design, the direct income effects show the government losing as it meets the full cost, vehicle operators gaining, and a very modest net gain to workers.

The gains by category (in \$ million) are:

Table 7.16 Distributional Effects (\$ million, Domestic Price Numeraire)

Groups	Gain/Loss			Total
Vehicle Operators: Change in VOC				159.77
Cars/Jeeps	65.53			
Light trucks	14.26			
Medium trucks	23.41			
Heavy trucks	33.70			
Buses	10.45			
Motorcycles	12.41			
Passengers: Time Savings	Work	Leisure	Total	24.29
Cars/Jeeps	0.00	1.97	1.97	
Light trucks	0.73	0.07	0.80	
Medium trucks	1.95	0.20	2.15	
Heavy trucks	1.18	0.12	1.29	
Buses	13.71	3.66	17.37	
Motorcycles	0.00	0.71	0.71	
Government: Project				
Project				-122.56
Taxes				-1.56
Forex Premium				5.12
Labor Wage Adjustment				
Vehicle operator				-8.90
Other labor (construction)				10.81
Net Benefit				66.96
VOC = vehicle operating cost. Source: ADB (2007).				

Vehicle operators	159.77
Passengers	24.29
Government	-119.00
Labor	1.91

Establishing how far a project impacts on poverty requires further information on what proportion of the benefits and costs accrue to households below the poverty line. This type of information normally

requires socioeconomic surveys of participants in the project locality; in a transport project, a further assumption is required as to how far VOC savings are passed on to consumers in lower prices. The original project report has no information on these issues. Hence, here assumptions are introduced for illustrative purposes only. It is assumed that:

- (i) there is strong competition in the freight sector so that 75% of benefits to truck operators are passed on in lower product prices and that the poor receive 10% of the value of these price reductions;
- (ii) there is also strong competition in the bus sector so that 75% of benefits to bus operators are passed on to passengers of whom 50% are poor;
- (iii) 15% of the benefits to motorcyclists are transferred indirectly to the poor, for example through family income sharing, even though the poor themselves are unlikely to own a motorcycle;
- (iv) 40% of the value of passenger time savings for cars, trucks, and motorcycles, and 50% of the value for buses go to the poor;
- (v) 40% of the wage losses for vehicle operators and 100% of the wage gains for construction labor go to the poor; and
- (vi) government income has an opportunity cost in terms of poverty reduction, so that of the net income used on this project, ultimately 10% would otherwise have gone to the poor.

The gains to the poor by category (in \$ million) are:

Consumers	5.35
Passengers	15.37
Workers	7.24
Motorcycle	1.86
Opportunity cost	-11.90
Total	17.93

As Table 7.17 shows, these assumptions give a net gain to the poor of \$17.93 million or a poverty impact ratio (share of the poor in economic NPV) of 27%.

Table 7.17 Poverty Impact Analysis (\$ million, domestic price numeraire)

Pass-on Rate →	Gain/ Loss	Operators	Consumers	Passengers	Share of Poor (%)	Gain/ Loss of Poor
		100%	75%	75%		
Vehicle Operators: Change In VOC						
Cars/Jeeps	65.53	65.53			0	0
Light trucks	14.26		10.69		10	1.07
Medium trucks	23.41		17.56		10	1.76
Heavy trucks	33.70		25.28		10	2.53
Buses	10.45			7.84	50	3.92
Motorcycles	12.41	12.41			15	1.86
Passengers: Time Savings						
Cars/Jeeps	1.97			1.97	40	0.79
Light trucks	0.80			0.80	40	0.32
Medium trucks	2.15			2.15	40	0.86
Heavy trucks	1.29			1.29	40	0.52
Buses	17.37			17.37	50	8.69
Motorcycles	0.71			0.71	40	0.28
Government Project						
Project	-122.56				10	-12.26
Taxes	-1.66				10	-0.16
Forex Premium	5.12				10	0.51
Labor: Wage adjustment						
Vehicle operator	-8.90				40	-3.56
Other labor (construction)	10.81				100	10.81
Total	66.96					17.93
VOC = vehicle operating cost. Source: ADB (2007).						

7.2.8 Sensitivity Analysis

It is now standard practice to apply sensitivity and risk analyses in transport project appraisals. Transport projects are generally sensitive to capital costs, projected traffic flows, and fuel costs. Traffic flows are generally sensitive to per capita income growth and the price elasticity used in traffic forecasts. For this case study, as traffic flows will be governed by income growth, income elasticity, changes in VOC, and price elasticity, the impact of changes in these parameters on the NPV and EIRR were examined separately. In addition, a scenario involving non-linear demand is considered as part of sensitivity analysis to illustrate the application of the numerical integration approach (as explained in Section 7.1.3). The sensitivity of the project to key parameters is also checked by identifying their switching values (that is, how far they have to rise or fall for the EIRR to reach 12% or the NPV to fall to 0), holding everything else constant. Table 7.18 summarizes the results.

Table 7.18 Sensitivity Results: Change in NPV and EIRR, Switching Values

	Change	NPV (\$ million)	EIRR (%)	Switching Value	Assumed Value
Base case		66.96	17.3		
Capital cost				54%	100%
	10%	54.58	16.0		
	20%	42.20	14.9		
Fuel				29%	100%
	-20%	47.86	15.8		
	-10%	57.39	16.6		
	10%	76.56	17.9		
	20%	86.19	18.6		
Income growth				1.027	1.06
	1.02	-9.84	10.90		
	1.10	217.90	23.8		
Price elasticity				0.6326	-0.5
	-0.90	109.31	20.1		
	-0.10	36.37	15.0		
Adjusted half VOC savings		57.72	16.6		

EIRR = economic internal rate of return, NPV = net present value.

Source: ADB (2007).

These results indicate that a rise in capital cost of 54% above the base case estimate is needed to render the project marginal. As fuel price is a significant element in VOC, the level of project benefits rises with the fuel price; however, only when the assumed fuel price falls by 29% will the project become marginal. On the basis of the assumed income elasticities, if income growth is 2.7% annually, rather than the assumed 6%, the project becomes marginal.

As regards price elasticity, its switching value is positive rather than negative. This means that the project is justified on the basis of cost savings on normal traffic alone and generated traffic is not needed as a justification. It will take a decline in traffic in response to the fall in VOC (which implies positive price elasticity) for the project to become marginal. As expected, the projected growth of income and the level of capital costs are the variables with the greatest impact.

The sensitivity of the results to the value of generated traffic was tested to illustrate the augmented approach to the rule of half. As set out in Section 7.1.3, this involved identifying four new price points on the demand curve for generated traffic and calculating the consumer surplus area corresponding to each. The total consumer surplus was then divided by total generated traffic to give an average WTP per vehicle-km, which was used instead of half the VOC saving per vehicle-km to value the generated traffic component of benefits. The present value of benefits from generated traffic based on the numerical integration approach is \$33.26 million, which represents a 17.8% reduction from the base case value of \$40.45 million. The resulting NPV of \$57.72 million and EIRR of 16.6% indicate that the project is still acceptable, which is expected since the sensitivity analysis has shown that the project can be justified on the grounds of cost savings for normal traffic alone.

7.2.9 Risk Analysis

Risk analysis incorporates simultaneous changes in all key variables specifying a probability distribution for variation and, where necessary, ensuring that variables that are expected to be correlated a-priori change together. The project is tested for risk by varying key parameters simultaneously within what are considered to be a reasonable range. Variation is taken to follow a normal distribution. Table 7.19 gives the parameters that are varied and the range within which they vary. Modest

variation of capital cost and much higher variation of the fuel price are allowed for, as well as changes in income growth and price elasticity of demand.

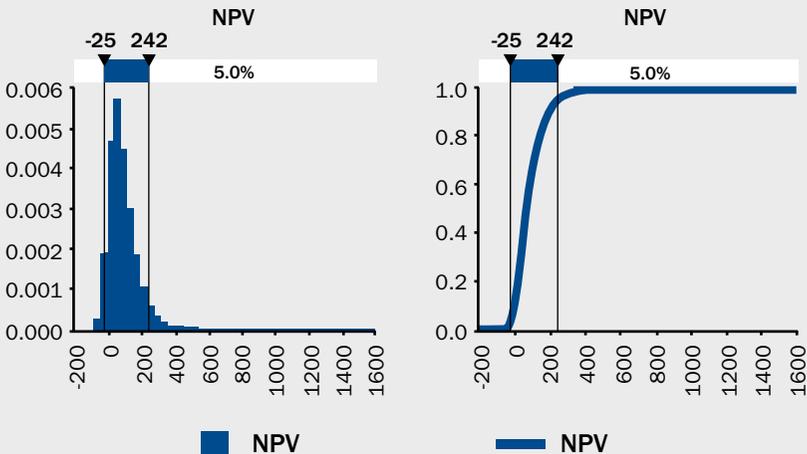
Table 7.19 Risk Analysis: Parameter Variation

Parameter	Range (Base Case)
GDP growth, annual	2% to 10% (6%)
Price elasticity	-0.9 to -0.1 (-0.5)
Capital cost	-20% to +20% of base case
Fuel price	-50% to +50% of base case

GDP = gross domestic product.
Source: ADB (2007).

The resulting expected value, that is, the probability weighted NPV is \$83.2 million, approximately 24% higher than the base case (Figure 7.3). The key result is the probability of project failure, defined by a negative

Figure 7.3 Risk Analysis: Probability Distribution of NPV



Minimum	-95.4331
Maximum	1,564.9006
Mean	83.1918
Std Dev	86.7300
Values	10,000

NPV = net present value, Std Dev = Standard deviation.
Source: ADB (2007).

NPV. This probability is about 10% and while there is no unique cut-off rate for acceptable risk levels (although 25% is sometimes used as a rule of thumb), the project appears to be low risk.

7.2.10 Conclusion

The case study has shown how an ADB road project can be analyzed using a relatively simple practical approach. The analysis is partial in that no sector modeling of shifts between transport modes is attempted, and the valuation of more complex aspects like traffic accidents or air pollution is not attempted. Nonetheless, the original analysis is extended in a number of aspects and key areas for further attention are highlighted.

8. Appraising Electricity Projects

8.1 Introduction

This chapter presents key features of the economic analysis of power sector projects, focusing on the methodology for benefit valuation. It also considers expansion aspects of demand estimation and can be applied to valuation of the expansion of the system as a whole. Chapter 9 presents two case studies on power transmission and generation projects, illustrating the application of the methodology.

The methodology for the economic analysis of power projects—particularly the methods for estimating benefits—has not undergone significant changes since the late 1980s. However, least-cost expansion planning in the energy sector has advanced with the availability of better computing facilities. The methodology for estimating benefits, in particular the willingness to pay (WTP) for incremental energy consumption, continues to rely on simple approximations in practice (Devicienti et al. 2004). Use of demand information generated from econometric techniques in assessing benefits has been rare despite increased availability of demand functions for electricity in developing countries.

The characteristics of the power sector and the context under which the investments are made, are important in identifying and estimating the benefits of power projects. In most cases, development banks, governments, or private investors may finance only one component of the power investment program at a given time. Isolating the benefits of the financed component is difficult because of the interdependency of various components in the system to produce the final outputs. The power investment program has to be analyzed as a package (known as

the systems approach) in undertaking economic analysis when such interdependencies exist.

Transmission lines are a good example in which benefits cannot be isolated easily because without certain generation and distribution facilities, the final output may not reach consumers.¹ A peaking plant to meet the additional peak demand due to the shift in load duration curves, is another example where the systems approach is often appropriate. In some cases, the peaking plant not only helps meet the peak load demand, but also releases the capacity of the existing plants to meet the base load, resulting in additional system-wide generation. In such situations, the system-wide impacts should be considered in the economic analysis.

Whether a systems approach² is necessary or whether an individual project should be subjected to cost–benefit analysis (CBA) needs to be resolved at the early stage of the economic analysis of energy projects. Often, power generation projects can be analyzed as independent projects. However, if the power project requires dedicated transmission and or distribution facilities to dispatch the generated power, the cost of the additional facilities should be incorporated in the project analysis.

8.2 Estimating Benefits

As in other sectors, a key step in identifying the economic benefits of a power generation project is to distinguish between incremental and non-incremental output. As explained in previous chapters, incremental output refers to the additional output produced by the project over and above what would be available in the without-project situation. Non-incremental output is output produced by the project that displaces high-cost or unreliable supplies available without the project. The economic values of incremental output and non-incremental output are referred to as incremental benefits and non-incremental benefits, respectively.

Early literature on power project assessments distinguished between existing and new markets. For example, the reference by Ali (1989) to existing markets and new markets corresponds to what are now termed non-incremental and incremental output. In other literature (Munasinghe 1990, Webb and Pearce 1985), new markets refer to areas where there is

¹ There are exceptions, for example, if the transmission line replaces an old one to avoid energy losses, in which case, the project can be analyzed as an individual project.

² See Ali (1991) for a detailed discussion on the systems approach for appraising power projects.

no prior access to electricity or inaccessibility of existing supplies for technical reasons. In this definition of new markets, the main issue is the absence of previous data to estimate demand for assessing incremental output. The new and existing market distinction is now superseded by the incremental and non-incremental framework as potentially incremental and non-incremental outputs occur in both existing and new markets.

Another important distinction is the size of projects. In the case of small projects, a perfectly elastic demand can be assumed, and benefits are equal to project revenues. However, it is commonly assumed that a perfectly elastic demand is very rare in energy projects (Webb and Pearce 1985, Ali 1989). In the case of large projects, the usual downward sloping demand curves are relevant and benefit estimation should consider both revenue and consumer surplus effects.

Power generation projects add capacity in the system to: (i) expand supply for meeting growing demand; (ii) reduce costs to the utility by displacing old facilities, or rehabilitating aging, poorly-functioning facilities; and (iii) improve the reliability of electricity supply. Additional supplies of electricity are required for different reasons such as: (i) to serve a new market where no electricity is available, (ii) to reduce a shortage in existing markets where supply is inadequate to meet growing demand, and (iii) some combination of the above situations.

Supply expansion carried out in a rural area with no prior access to electricity—together with transmission and distribution components—is often referred to as a rural electrification project. Projects displacing or rehabilitating old generation facilities reduce high generation and operating and maintenance costs. In many occasions, additional electricity supply also improves reliability and reduces system costs. In each of these situations, different forms of incremental and non-incremental benefits occur. Understanding the purpose of the project is imperative for the identification of benefits.

8.2.1 Power Generation: Supply Expansion

This section discusses the estimation of benefits for different categories of power generation projects. For the purpose of exposition, the issues of benefit estimation are discussed in relation to the different purposes of supply expansion. For each category, the discussion uses a simple

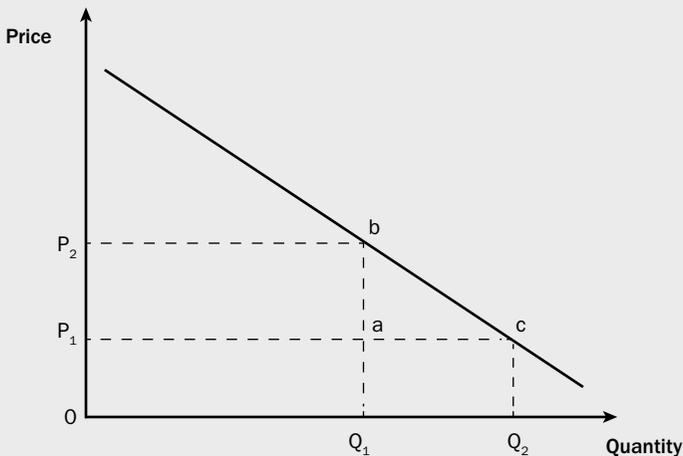
demand-supply framework to conceptualize benefits, before discussing problems of estimation.

A: Serving New Markets

Supplying electricity to a new market is a simple case involving both incremental and non-incremental benefits. For simplicity, it is assumed that electricity is used only for lighting and currently, kerosene oil is used for this purpose. As shown in Figure 8.1, the project displaces the current use of kerosene and induces additional use of electricity due to its lower cost. Initially, kerosene consumption is Q_1 (electricity equivalent) and its cost is P_1 . The project displaces this energy use and in addition increases electricity consumption by $Q_2 - Q_1$. The distances $0Q_1$ and $Q_2 - Q_1$ represent non-incremental and incremental outputs, respectively. The non-incremental benefit is represented by area P_2baP_1 which is the resource cost savings on kerosene. The area Q_1bcQ_2 represents incremental benefits and it has two distinct components: sales revenue from incremental output (area Q_1acQ_2) and the consumer surplus (area abc).

Part of the information required to undertake benefit estimation such as the kerosene price and the quantity purchased (equivalent to the electricity quantity Q_1), can be collected through a survey in the project area. The price of electricity (P_2) which should be set at the estimated

Figure 8.1 Benefits of Supplying Electricity in a New Market



long-run marginal cost of electricity supply, should be known to the analyst. The unknown information at the time of project preparation is the incremental output. The usual practice is to undertake a survey in similar recently electrified areas to identify incremental consumption and assume that a similar increase will take place in the project area. Once this information is gathered the estimation of benefits is straightforward.

The above method of estimating benefits is popular with practitioners because the analysis can be undertaken without requiring information from econometrically estimated demand functions for electricity. There are however, weaknesses in this simple method.

When households use electric lights to replace kerosene lamps, not only is there a change in monetary costs, but the lighting quality clearly improves. It is difficult, if not impossible, to value the benefits of power supply taking into account the improvement in output quality.³ Some studies have used demand for lumens—a measure of light emitted—rather than demand for electricity to value benefits of rural electrification projects (See ESMAP 2003). In this approach, kerosene and electric lamps are compared on the basis of lumens they produce. Even so, some other benefits from using electric lighting to substitute for kerosene lamps, such as cleaner indoor air and improved safety through reduced fire risks will still be missing. Therefore, cost savings estimated by using the expenditure on kerosene provides only a lower bound for the non-incremental benefits of electricity.

Aside from lighting, the most common use of electricity in rural households is for watching television. Car batteries are used to operate televisions in some regions without electricity. The costs saved on car batteries and any similar alternative source of energy costs should also be included in estimation of non-incremental benefits.

The above method illustrated in Figure 8.1, assumes that the demand function is linear and that it does not shift due to an income increase during the project period. The analysis can be extended to relax the linearity assumption following Choynowski (2002). The non-linear demand function can be defined as a semi-log function:⁴

³ The shift from inferior sources of lighting to electricity can also be viewed as an upward shift in demand for energy. If such an approach is followed, the benefit estimation will be different. In addition to incremental and non-incremental benefits, there will be additional consumer surplus (see Ali 1989). However, in the absence of the demand function and without knowing its actual shift, one cannot use this approach in practice.

⁴ The semi-log functional form is preferred because it is easy to estimate and is consistent with underlying microeconomic theory.

$$\ln q = \alpha + \beta p \quad (1)$$

where \ln is the natural logarithm and $\alpha > 0$, $\beta < 0$, q is quantity, p is price. The price elasticity (η_p) is given by:

$$\eta_p = (dq / dp) (p/q) = \beta p \quad (2)$$

where d is the change in quantity or price. This functional form also has the desirable property that marginal WTP rises exponentially as quantity demanded falls, as suggested by economic theory. The parameter α depends on income, prices of other energy forms, and other non-price variables that determine the demand for electricity. This functional form lends itself readily to calculating the incremental economic benefit (EB) of electricity. The economic benefit is simply the area beneath the demand curve between the existing and new outputs (q_1 and q_2), that is,

$$EB = \int_{q_1}^{q_2} p dq \quad (3)$$

where q_1 to q_2 is the range of integration. Integrating with respect to q results in an economic benefit of

$$EB = q_2(p_2 - 1/\beta) - q_1(p_1 - 1/\beta) \quad (4)$$

where p_1 and p_2 are prices corresponding to q_1 and q_2 , respectively.

The information on q_1 , p_1 , and p_2 should be readily available to the analyst. Information on q_2 can also be obtained through a survey of a similar recently electrified area. Use of the above formula to estimate benefits require information on β , the slope of the demand function. The econometric approach to estimating the demand function that allows the derivation of β is explained in the following section. However, estimating a demand function is not often feasible in many practical appraisals of energy projects.

When the estimated demand function is not available, survey data can be used to estimate benefits. The electrification of a village in a rural area is used here as an illustrative example. This approach usually begins with a survey of two villages: the village to be electrified, and another village already electrified but with similar economic and demographic characteristics. The differences in the consumption of all energy in these villages may therefore be attributed to the electrification project.⁵ The survey may find that households without access to electricity

⁵ Finding a similar village without electricity as a control is not easy and this approach only provides a proxy for the relevant data.

use kerosene for lighting while those with access use electricity for lighting as well as for fans, radios, televisions and so forth. Other energy consumption, for example, gas for cooking, may remain the same for both villages. A representative household pays \$0.20/kWh-equivalent for kerosene and consumes 30 kWh-equivalents per month. These numbers correspond to p_1 and q_1 in equation (4).

Billing data for households in the electrified village shows that, at a price of \$0.08/kWh, households on average consume 60 kWh of electricity per month. Therefore, with the electrification project, consumption is expected to rise to 60 kWh per month in the non-electrified village, or an incremental 30 kWh per month. This corresponds to q_2 in equation (4). The parameter β in equation (4) reflects the change in demand in response to the change in price and so it can be estimated as:

$$\begin{aligned}\beta &= (\ln q_2 - \ln q_1) / (p_2 - p_1) \\ &= (4.09 - 3.40) / (0.08 - 0.20) \\ &= -5.78\end{aligned}$$

The economic benefit of the incremental 30 kWh per month consumption given by equation (4) is calculated as:

$$\begin{aligned}EB &= q_2(p_2 - 1/\beta) - q_1(p_1 - 1/\beta) \\ &= 60(0.08 + 0.17) - 30(0.20 + 0.17) \\ &= \$3.903\end{aligned}$$

Note that the above benefit represents incremental benefit. Non-incremental benefits (resource cost savings or the avoided expenditure on kerosene) should be added to the above to estimate the total benefits of the project. If benefits are estimated at the household level they should be adjusted for the entire project area by multiplying by the number of beneficiary households. Devicienti et al (2004) point out that even with this generalization of the functional form, this approach (which uses only two data points) is less rigorous than the use of econometrically estimated demand functions (which use more than two data points and have higher predictive power). Therefore the above method should be viewed as a simplification.

In addition to households, electricity is used for agricultural, industrial, and commercial purposes in the new area. For such purposes, electricity is generally used as an intermediate input to produce output. Here, the benefits can be valued by the marginal revenue product of electricity (that is, its physical marginal product times the price of

output produced) where marginal product is the extra output produced by one more unit of electricity. Applying this method requires estimation of production functions which is not easy in practice.

Given the difficulties in determining the marginal product of electricity in various agricultural, industrial, and commercial production activities, the benefits of electricity consumption in these sectors are often measured in terms of costs of potential substitutes. Carefully designed surveys can generate data on actual use of alternative sources of energy which will be replaced when electricity is available and the resource cost savings can be considered as the benefits of electricity supply. Since there is also a potential incremental increase in production activities due to the availability of electricity as well as other benefits—like improvement in the quality of life and changing attitudes—that are extremely difficult to quantify, this approach yields an underestimate (Munasinghe 1990).

B: Reduction in Power Shortages

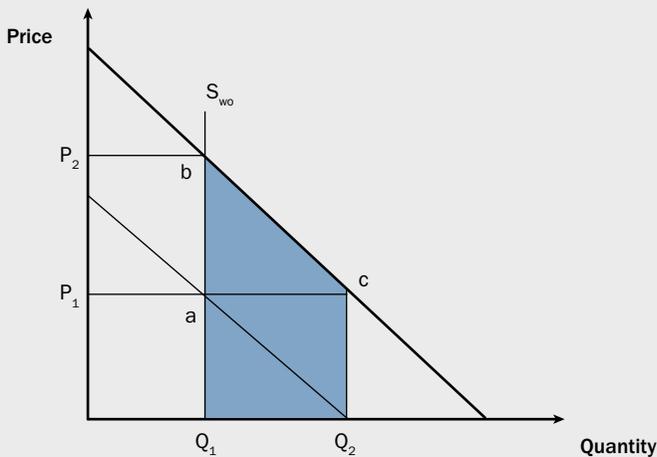
One of the main weaknesses in the above approach is the assumption that the demand function does not shift due to income effects during the project period. Usually, power generation facilities last a long time and it is unrealistic to assume that demand remains the same in a growing economy. Hence, the basic model needs to be extended to accommodate the impact of a shift in the demand curve.

The first type of project considered in this scenario adds power generation capacity to the system, where power shortage is present. In Figure 8.2, S_{wo} is the fixed supply without the project. The electricity price is set at P_1 which is equal to the long-run marginal cost. Supply is constrained at the current level of output, Q_1 . As the demand for electricity shifts to the right in the absence of a price control, the without-project price will increase from P_1 to P_2 . However, price adjustments will not take place automatically if price is administratively determined. Thus, the market mechanism that rations consumption to allocate limited supply to those consumers who value it the most fails and the without-project situation results in power shortages. Assume that the supply constraint is removed by adding a power plant that produces $Q_2 - Q_1$ of electricity. The main difference, compared to the previous case, is that the project only has incremental benefits demarcated by the shaded area (Q_1bcQ_2).

There is no resource cost saving because electricity supply was not displaced by the project.

As a slight variant of the above case, we can assume that the price is increased to P_2 as a demand management measure until the next power project is commissioned and is reduced to the original price P_1 after the commissioning of the new project. Benefits in this case will have an additional component as shown in Figure 8.2. Under the without-project situation the P_2baP_1 area of consumer surplus is lost due to the price increase from P_1 to P_2 . When the price is brought back to P_1 with the new project, the P_2baP_1 area of consumer surplus should be added to the project benefits (area Q_1bcQ_2). However the consumer surplus effect is a benefit only for consumers, not for the economy, as it represents a transfer between them and the electricity authority, which will lose P_2baP_1 in revenue. This example shows that understanding the context under which the energy generation project is added to the system is important for the identification of benefits.

Figure 8.2 Shift in Demand Without Price Change

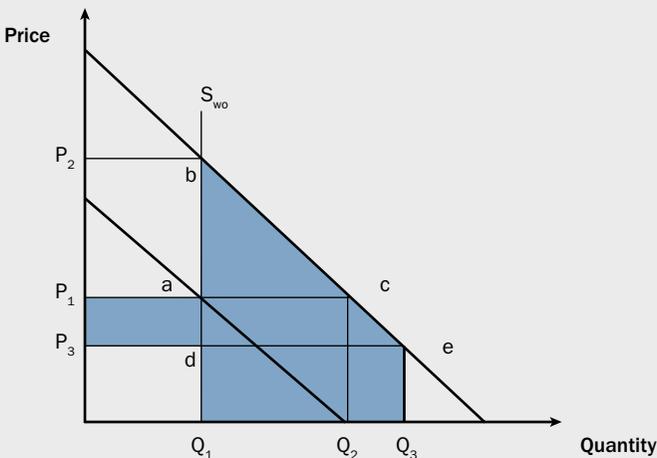


Another variant may occur if the new power plant is large and its unit cost is lower than the previous marginal cost to the system due to its application of a new technology. In the previous cases, the unit cost of electricity was assumed to be constant. Now with the new project, the

long-run marginal cost of electricity in the system may be reduced from P_1 to P_3 (Figure 8.3). One of the main differences in this case is that the incremental benefit to consumers is larger now due to both income and price effects. Although there is no displacement, average cost has gone down with the project. The power generated by old power plants also sells at a lower price of P_3 .⁶

Therefore, there is an additional price reduction that accrues as consumer surplus which is equal to area P_1adP_3 . As in the previous case, if the older plants continue to operate at a higher unit cost, the area P_1adP_3 is a benefit to consumers but a transfer as far as the economy is concerned due to the revenue loss to the electricity authority. In this case, the total consumer benefit is equal to incremental benefits (area Q_1beQ_3) and the consumer surplus increase (area P_1adP_3). However, the latter does not count as far as the economy as a whole is concerned, and therefore is not accounted for in the economic analysis of the project.

Figure 8.3 Shift in Demand with Price Change



In the practical application of the situation depicted in Figure 8.2, the analyst has access to information on electricity price (P_1), without-project output (Q_1), and with-project output (Q_2-Q_1). The total benefits can be

⁶ It is generally not feasible to charge different prices for electricity produced by different plants for technical and political reasons. Transaction costs of such a differential pricing scheme will also be high and therefore having a uniform price reflecting the system-wide long-run marginal cost is the most common approach to pricing.

divided into two: (i) project revenue (area Q_1acQ_2); and (ii) consumer surplus (area abc). Estimation of project revenue is straightforward but the area abc cannot be estimated without knowing the demand function because price P_2 can never be observed. In some practical applications, only the project revenue is considered as a proxy for benefits and that is clearly an underestimate. A particular concern is that if the cost of carbon and other environmental pollution effects of energy generation are incorporated into the economic analysis, economically viable projects may fail cost-benefit tests with this type of proxy that underestimates the benefits of the project.

The consumer surplus portion of the benefits (area abc) can be computed as half of $P_2 - P_1$ times project output. In practice, various proxies are used in place of the unknown P_2 . The cost or price of alternative energy sources in the second-best option, in the least-cost solution or, alternatively, the cost of current alternative energy sources such as kerosene in areas where electricity is unavailable without the project, are commonly used proxies. These proxy methods⁷ are not backed by theory and they are further problematic because it is unclear as to how many people would consume, given a more costly option. The theoretically correct approach for estimating the total WTP (area Q_1bcQ_2) for the increased power supply is to integrate the demand function over Q_1Q_2 . Even if the demand function is known, it is not possible to use this approach without knowing the exact shift due to a change in income. An alternative approach is to use the price elasticity of electricity demand to estimate consumer surplus.

It can be shown that the consumer surplus (area abc in Figure 8.2) is equal to:⁸

$$CS = 0.5[P_1 (\Delta Q)^2] / [e_d Q_1] \quad (5)$$

where ΔQ is the project output ($Q_2 - Q_1$) and e_d is the absolute value of the price elasticity of demand.

The key difference between equation (5) and the analysis underlying equations (1) to (4) is that (5) does not require an estimate of the without-project price P_2 . Given that P_1 , Q_1 and project output are known, the only additional information required to estimate the consumer surplus from (5) is the price elasticity of demand. Compared to the use of the demand

⁷ If there is widespread use of generators when power shortages occur, the cost of generators is a reasonable proxy for P_2 . However there will always be a proportion of consumers who will not use generators, and therefore strictly the calculated price cannot be assigned to value their benefits.

⁸ See Webb and Pearce (1985) for the derivation.

function and its integration to calculate the total WTP, the use of price elasticity provides a practical approach to estimate benefits. When the elasticity for a particular country is not available, a proxy can be applied based on elasticity estimates in similar countries; sensitivity analysis can be undertaken on the range of elasticity values to check how project benefits vary with changes in the elasticity (see Appendix 8.1).

In the case of a price decrease as depicted in Figure 8.3, the WTP for the incremental energy supply is equal to $Q_1 \times beQ_3$, which has both revenue and consumer surplus components. Consumer surplus (area *dbe*) is difficult to estimate. Equation (5) can be used here with the necessary modifications (here, ΔQ is equal to $Q_3 - Q_1$). The consumer surplus due to a price drop is easy to estimate as it is equal to the price difference times the without-project quantity.

The method described so far on the estimation of benefits of incremental consumption of electricity relies on the revealed preference method, which uses market data that shows actual consumer responses to price change. However as with other sectors, the benefits of an electricity project in principle, can also be estimated using the contingent valuation (CV) method (see Box 8.1).

Box 8.1 Use of Contingent Valuation Method in Power Projects

Following the same approach described in Chapter 4, households which are going to be connected to the electricity in the new supply area can be interviewed to find out their willingness to pay (WTP) for electricity. The distinction between incremental and non-incremental benefit can be disregarded and electricity can be treated as a single output in the application of this method to households which currently do not have access to electricity. Relative to other methods, the contingent valuation (CV) method generates a comprehensive measure of the total value of electricity. When demand data are difficult to obtain the CV method provides an alternative to estimate the benefits of electricity.

1. The CV method can also be used to estimate WTP for various aspects of energy sector improvements. For example, the Tata Energy Research Institute in India undertook a study in 2001 to estimate the WTP for improving service reliability (or the WTP for avoiding unserved energy) among farmers and industries. An et al. (2002) undertook a study in the People's Republic of China to study the choice of switching from fuelwood to electricity, and Lampeitti et al. (2004) undertook a CV study in Azerbaijan to assess the demand for service improvements. O'Garra et al. (2007) compare public WTP for air

continued on next page.

Box 8.1 continued.

pollution reductions associated with a large-scale introduction of hydrogen fuel cell buses in four cities: Berlin, London, Luxembourg, and Perth using the CV method. Koundouri et al. (2009) used a CV study to elicit public attitudes toward renewable energy generation and their WTP for the construction of a wind farm in the area of Messanagros in the island of Rhodes, Greece. Damigos et al. (2009) used the CV method to explore households' perceptions and WTP for the security of natural gas supply for electricity production in Greece.

2. Application of the CV method in the power sector, however, is limited compared to other utility services such as water supply and sanitation. The main limitation of the CV method—dependency of the quality of WTP estimates on questionnaire design and the respondents' knowledge and understanding of the CV scenarios—may be the main reason for this. In addition to this basic shortcoming, application of the CV method to estimate benefits of power projects is difficult for a number of reasons. People are not used to thinking of electricity consumption in terms of kWh. Complicated tariff systems add to these difficulties. Sometimes, respondents in developing countries do not believe that electricity service reliability can be improved because they have been experiencing power cuts and voltage fluctuation for long periods of time. Therefore, the scenario rejection rate can be high in power sector CV studies. In some developing countries, electricity tariffs for industries and commercial establishments are higher than long-run marginal costs. These higher tariffs also lead to a higher scenario rejection in CV studies.

Because of these difficulties, careful design of CV studies and undertaking focus group discussions and pre-tests are very important in CV studies in the power sector. Devicienti et al. (2004) conclude that it is increasingly feasible and desirable to use CV studies in developing countries to help evaluate a wide range of projects. However, more field research on the applicability of the CV method in developing countries is needed before scaling up its use in the power sector.

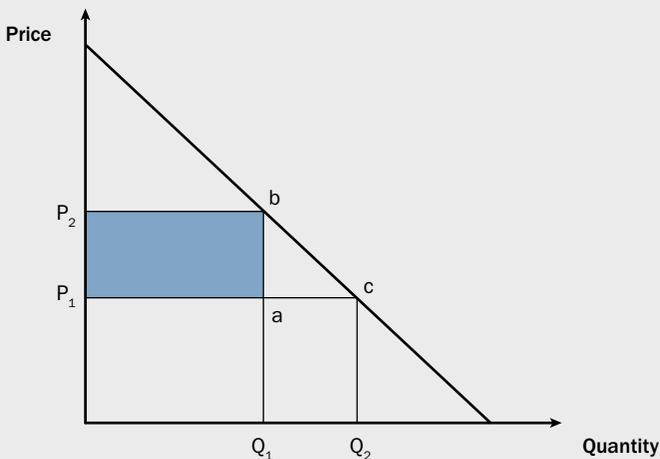
8.2.2 Power Generation: Reduction in Generation Costs

The previous section discussed benefit estimation under different contexts of supply expansion. Power projects are also built to reduce generation costs by displacing or rehabilitating old facilities that possessed low generation efficiency, higher generation loss, or higher operating and maintenance (O&M) costs. If the tariff remains fixed and

the output is the same, project benefits are solely non-incremental (resource cost savings) as illustrated by the shaded area (P_2baP_1) in Figure 8.4 and they accrue to the electricity authority, not the users. If the tariff is reduced to P_1 after replacing the old or higher cost plants, and the new plant has the capacity to produce additional electricity, there will be incremental output ($Q_2 - Q_1$). The incremental benefit will be equal to area Q_1bcQ_2 which has a revenue component [$P_1^*(Q_2 - Q_1)$] and a consumer surplus component (area abc). The total benefits are equal to the sum of non-incremental and incremental benefits. Here, non-incremental benefits (area P_2baP_1) accrue to consumers who enjoy the lower-priced electricity. Data issues in the application of these methods are similar to those described earlier.

The cost savings benefits of the saved resources, such as fuel, equipment, and labor should be measured in economic prices. For generation equipment and fuel, which are largely traded, the economic prices are their border prices. Non-traded goods (and labor services) are valued at market prices, adjusted by the appropriate conversion factors to take into account market distortions and government interventions. Saved labor costs generally account for a very small portion of resource cost savings in power generation projects.

Figure 8.4 Benefits of Cost-Reducing Power Projects



8.2.3 Power Generation: Improvement in System Reliability

The quality of electricity supply is broadly defined by the reliability of service, which is further defined by frequency and duration of interruptions, and the extent of voltage and frequency variations (Munasinghe 1990). The demand for service reliability in the electricity sector is largely characterized by outage costs (Caves et al. 1990), which refer to loss of consumer welfare as a result of the power outage. Power shortages manifest at the consumer level in several ways, including complete supply interruptions (blackouts), frequency and voltage reductions (brownouts), and sudden sharp fluctuations in frequency and voltage. Improvements in reliability often constitute the main reason for having power rehabilitation or displacement projects, particularly when unreliable power supply imposes substantial costs on consumers.

While new power generation projects with the sole objective of improving reliability are uncommon, many projects may have a sub-objective of improving the reliability of the system. When an energy project has a distinct component of reliability improvement, the benefit of avoided outage costs can be added to the benefit stream of the project.

Outage costs can be estimated using various methods. One of the most common in practice is the cost of back-up generators, so that, if reliability improvements displace back-up generating facilities, the cost of back-up generators can be considered as resource cost savings.⁹ Survey methods have also been employed to establish the actual costs incurred by a household or business during power interruptions. A direct survey method produces reasonably good estimates of outage costs for industrial and commercial customers but its application is difficult for residential customers, who may find it difficult to put a monetary value on the inconvenience created by power interruptions.

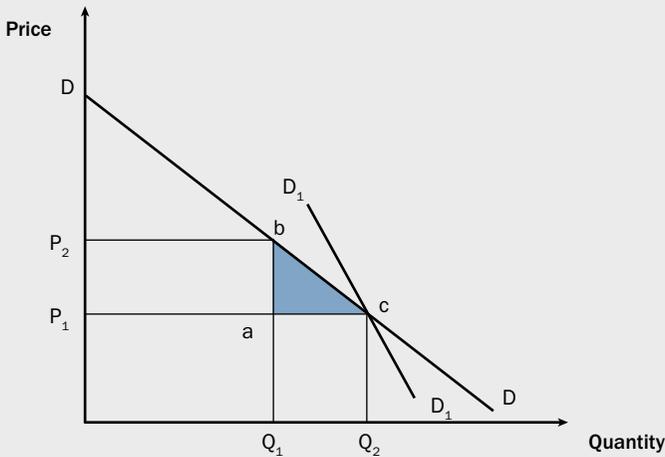
In addition, estimated demand functions can be used to estimate outage costs and this method is preferred by many. In fact, the reliance on other methods is often due to lack of demand information for estimating these costs. Figure 8.5 depicts the conceptual framework for using consumer surplus to estimate outage cost. The outage forces the consumer to reduce consumption from Q_2 to Q_1 . This effect is

⁹ Caves et al. (1990) categorize methods of estimation of outage costs into three: (i) proxy methods, (ii) survey methods, and (iii) reliability demand methods and give examples of each.

conceptually equal to the increase in price from P_1 to P_2 . Total welfare loss due to a reduction in consumption is equal to the area under the demand curve between Q_2 and Q_1 (the area Q_2cbQ_1). Of this total welfare loss, consumers incur only the loss of consumer surplus (area abc) because they save part of the electricity bill (area Q_2caQ_1).

The main advantage of this method is that it is based on the actual behavior of consumers and the method can estimate the cost of a partial outage. Its limitation lies in its inability to take into account short-run responses to outages and the warning time involved. The demand curves usually available (such as DD in Figure 8.5) are based on the assumption of advanced warning on price changes so that consumers have time to adapt. Consumer response to outage and a price change is similar and response to an outage is best represented by a short-run demand curve like D_1D_1 .

Figure 8.5 Estimation of Outage Cost



Source: Adapted from Caves et al. (1990).

8.2.4 Power Transmission

Power transmission projects link generation capacity with a distribution system. As such, they facilitate the flow of power from power plants to

users and can create no value independent of other parts of the power supply network. A transmission project may be designed to: (i) evacuate power from a plant to the grid, (ii) open a new area to the supply of electricity from the grid (often in rural electrification programs), (iii) increase supply capability in an area already connected to the grid, (iv) provide an alternative route for the transmission of power, (v) provide interconnection between two grids, and (vi) rehabilitate and replace transmission lines to reduce transmission losses. In most of these cases, the benefits of the transmission line cannot be separated from the power system.

It is common to appraise power expansion programs considering the entire system without separating returns to transmission, on the grounds that all aspects of the program are interrelated and transmission cannot function in isolation. Generally, a two-step procedure can be used to analyze the power system: First, by the determination of the least-cost expansion plan given the existing configuration of the power system, demand forecast, and available alternative system expansion plans; and then a CBA to assess the economic viability of the least-cost expansion program (see Ali 1991).

Identification of the least-cost expansion plan over a given period should in principle allow for interactions among costs, tariffs, and demand. In the systems analysis, even if the concerned component is a major part of the expansion plan, the project calculations will give the return to the program as a whole, not to a single component—whether transmission, generation, or distribution.¹⁰ Hence, over a given time horizon, program *j* should be the least-cost form of meeting an output target and the net present value (NPV) of the incremental investment involved in the expansion should exceed zero at the given discount rate. This requires:

$$\frac{PV(Bni_j + Bi_j) - PV(CAP_j + OM_j + E_j + D_j)}{PV(CAP_n + OM_n + E_n + D_n)} > PV(Bni_n + Bi_n) - \quad (6)$$

where *j* refers to the scenario with the expansion and *n* to the without-expansion case; *Bni* and *Bi* are non-incremental and incremental benefits, respectively; *CAP*, *OM*, *E*, and *D* stand for capital, operating and maintenance, energy, and distribution costs, respectively; and *PV* refers to discounted present value.

¹⁰ Stand-alone power distribution projects also can be appraised using the systems approach.

There are exceptions where benefits of transmission lines can be estimated without considering the entire system. An example is the rehabilitation or replacement of an old transmission line in which the benefits of reduced transmission losses can be directly attributable to the project. Also, when a transmission project is a discrete component of an expansion plan and the power transmitted by the project can be identified as displacing a particular set of alternative power suppliers in a given area, it is possible to calculate the benefits of the transmission project. This is provided that the least-cost expansion plan, of which the transmission project is a component, has already been identified and overall the expansion is justified (so the condition in equation [6] is met). Implicitly, all benefits from the transmission scheme will be non-incremental as it simply replaces a higher cost source of supply and its justification requires that:

$$PV(CAP_k + OM_k + E_k + D_k) > PV(CAP_t + OM_t + E_t + D_t) \quad (7)$$

where t refers to transmission project t ; capital (CAP), and operating and maintenance costs (OM) refer only to transmission by t ; and energy cost (E) refers to the cost of energy to be transmitted by t ; k refers to the alternative supply source to the power transmitted by the project.

The low-cost electricity provided by the transmission line sometimes results in an incremental increase in consumption. In this case the incremental benefits, valued at WTP, should be added to the non-incremental benefits. Estimation of benefits of independent transmission lines under these circumstances can be undertaken using the benefit valuation approach described above.

8.3 Demand Forecasting

The energy demand forecast is the starting point for the economic analysis of a power project. Electricity demand assessment provides basic information for both least-cost analysis (LCA) and CBA. As explained earlier, the price elasticity derived from demand equations constitutes key information for the estimation of benefits. Although a power generation project may be proposed to close a current demand-supply gap, there is a need to obtain a reasonably good estimate of how the demand for electricity will change in the medium to long term. The costs of overestimation and underestimation of future demand for electricity

are both substantial. Overestimation of electricity demand leads to economic waste—a large amount of capital with high opportunity costs will be wasted for a long period of time. Underestimation of electricity demand results in continuous under-provision of power and a lost opportunity for improving social welfare. The costs of underestimation or overestimation are generally much higher than the cost of undertaking a rigorous demand study (Munasinghe 1990).

However, forecasting electricity demand with a high degree of precision is difficult since demand for electricity is highly correlated with the economic performance of a country, which in turn is determined by a variety of factors.¹¹ In the power sector, a distinction is made between demand for *energy* (electricity expressed in terms of kilowatt-hours, megawatt-hours, etc.) and for *power* (capacity to deliver energy expressed in terms of kilowatts, megawatts, etc.). Meeting demand for electrical energy at all times requires power or capacity to meet peak demand. The load or capacity factor—the ratio between total energy produced and delivered and the capacity to deliver that energy (also specified as the ratio of the average load to the peak load)—is an important variable in demand forecasting. Generation losses, transmission losses, distribution losses, and theft (in some countries) should also be taken into account in forecasting electricity demand, particularly the demand for power.

Demand forecasting is normally done using one of three methods:

- (i) trend analysis,
- (ii) end-use models and customer surveys, and
- (iii) econometric methods (Sanghvi et al. 1989).

Trend analysis extrapolates the future demand using time series data on peak demand for power (kW) and annual demand for electricity (kWh). This method extrapolates future electricity demand based on past growth trends, assuming there will be little change in the pattern of major determinants of demand such as prices, incomes, and consumer tastes.

Forecasts are either on aggregate demand for the entire country or separately for different sectors. The main advantage of this method is its simplicity and modest requirements of both data and analytical

¹¹ Recent experience shows that the over-optimistic outlook assumed in demand forecasts of some Asian countries in the 1990s resulted in a long period of excess power supply after the 1997/98 Asian financial crisis. Unexpected economic slowdown due to the financial crisis reduced the demand for electricity significantly in some countries and demand forecasts had to undergo major revisions as a result.

skills. The major disadvantage is that this method does not attempt to understand the causes of past trends and may simply assume that the same trend will continue in the future.

Alternatively, as popularly used in practice, one can borrow results from trend analysis on economic growth and apply the income elasticity of demand for electricity to the forecast economic growth. The income elasticity of demand for electricity—defined as the ratio of the percentage change of electricity consumed to the growth rate of gross domestic product (GDP) or income—quantitatively measures the relationship between electricity demand and economic growth. The elasticity of demand for electricity can be calculated using historical observations. The approach, while as straightforward as multiplying forecast economic growth with the demand elasticity, is subject to uncertainty. More sophisticated projections are based either on surveys of different consumer groups or on econometric estimates.

The econometric method is theoretically the most rigorous in that it identifies a systematic and statistically significant relationship between demand and its determinants. Using historical observations, the econometric models estimate the relationship between electricity consumption and a variety of other variables such as population, per capita income, prices of electricity and its substitutes, stock of appliances, industrial output, and weather conditions. Researchers have used a variety of models of electricity demand, sometimes using simultaneous equations to jointly estimate demand for stock of appliances and electricity use.¹² A commonly used time series model is the autoregressive distributed lag (ADL) model, represented as follows.

$$\log Q_t = \beta_0 + \beta_1 \log P_t + \beta_2 \log Q_{t-1} + \beta_3 \log I_t + X_t \Gamma + \varepsilon_t \quad (8)$$

where Q is demand; P is electricity tariff;¹³ I is household income; X is a vector of other factors such as stock of appliances, household demographics, output or sales, cost of substitute energy, and technological factors that affect energy efficiency; Γ is the corresponding coefficient vector; and t is time. Selection of variables in the X vector depends on the user sector.

The ADL model often fits the data quite well and yields reasonable price and income elasticity estimates. Time series models of this type

¹² See Espey and Espey (2004) for a detailed review of econometric modeling of electricity demand.

¹³ Given ADL estimates, one can calculate short-run price elasticity as $\eta_{sr} = \beta_1$, long-run price elasticity as $\eta_{lr} = \frac{\beta_1}{1 - \beta_2}$, and income elasticity as $\eta_y = \beta_3$.

are particularly suitable for projects adding to the total power supply of a country or region with dynamic economic growth (Pesaran and Akiyama 1998).

The forecasting procedure involves predicting Q_{t+1} given the independent variables for period $t+1$. The quality of a forecast depends on how far the model captures the relationships between electricity demand and all the factors which explain movements in demand and on the quality of the predicted values of the independent variables fed into the model, which are often outcomes of other forecasting models. It is good practice to estimate confidence intervals around the point estimates of future demand and undertake sensitivity analysis using lower and upper bounds. The narrower the interval, the more accurate is the forecast. Appendix 8.2 illustrates the use of a forecasting model for the Philippines.

8.4 Conclusions

This chapter has highlighted some key issues relating to benefit valuation, system planning and forecasting in relation to power projects. The conceptual principles involved do not differ from other sectors but particular features of the power sector mean that specific adjustments may need to be made in practical appraisals. Aspects of these are illustrated in Chapter 9 with case studies relating to both generation and transmission projects. The power generation project has a specific regional dimension.

Appendix 8.1 Price Elasticity Estimates

Use of econometrically estimated demand information—a price elasticity—avoids the use of proxies which are not backed by economic theory. The tables here summarize the results of estimates of the price elasticity of demand for electricity estimates in developing countries from both published and unpublished sources. The data on cross-study averages are relatively stable between different sectors in the range of -0.400 to -0.462 . The overall average of 34 estimates is -0.423 with standard deviation of 0.255 . The 95% confidence interval for the average is $(-0.334, -0.512)$, indicating that there is a 95% probability that the price elasticity will fall between -0.334 and -0.512 .

Table A8.1.1 Estimates of Price Elasticity for Electricity Demand

	Residential	Industry and Commercial	All Sectors	Overall
Asian Countries				
No. of observations	7	2	7	16
Average	-0.430	-0.246	-0.449	-0.415
Standard Deviation	0.194	0.007	0.375	0.275
Minimum	-0.15	-0.241	-0.03	-0.03
Maximum	-0.75	-0.252	-1.1	-1.1
Non-Asian Countries				
No. of observations	11	5	2	18
Average	-0.381	-0.548	-0.408	-0.43
Standard Deviation	0.288	0.112	0.155	0.242
Minimum	0	-0.43	-0.298	0
Maximum	-0.81	-0.67	-0.517	-0.81
All Countries				
No. of observations	18	7	9	34
Average	-0.400	-0.462	-0.439	-0.423
Standard Deviation	0.250	0.173	0.330	0.255
Minimum	0	-0.241	-0.03	0
Maximum	-0.81	-0.67	-1.1	-1.1
t-statistics	0.395	-3.608 ^a	0.145	-0.1715
P value	0.698	0.015	0.889	0.865

^a = significant at the 95% confidence interval.

Source: ADB staff estimates.

When an elasticity estimate is available for a country, it should be used to estimate consumer surplus changes as discussed above. When a country-specific elasticity is not available, the average elasticity for developing countries (-0.423) can be used to estimate benefits. It is good practice to look for unpublished demand estimates before using the average elasticity. Sensitivity analysis can be conducted using the upper and lower bounds of the elasticity values of the confidence interval (-0.334 , -0.512) to examine the impact of use of average elasticity values on project indicators.

Table A 8.1.2 Sources of Estimates of Price Elasticity of Electricity Demand

Country (Region)	Sector	Time Period	Estimates	Citation
Asian Countries and Region				
India (Urban)	Residential	1993–1994	-0.51	Filippini and Pachauri (2004)
India (Urban)	Residential	1993–1994	-0.42	Filippini and Pachauri (2004)
India (Urban)	Residential	1993–1994	-0.29	Filippini and Pachauri (2004)
Indonesia (15 regions)	All Sectors	1970–1979	-1.1	Amarullah (1983)
Malaysia	All Sectors	1960–1984	-0.11	Ang (1988)
Pakistan	All Sectors	1972–2007	-0.66	Arshad and Ahmed (2009)
Philippines (Metro Manila)	Residential	1970–1984	-0.5409	Francisco (1988)
Philippines (Metro Manila)	Commercial	1970–1984	-0.2515	Francisco (1988)
Philippines (Metro Manila)	Industrial	1970–1984	-0.2411	Francisco (1988)
Singapore	Residential	1975–1990	-0.35	Ang, Goh, and Liu (1992)
Singapore	All Sectors	1960–1984	-0.35	Ang (1988)
Sri Lanka	Residential	1952–2002	-0.75	Athukorala et al. (2009)
Sri Lanka	All Sectors	1970–2003	-0.03 ^a	Amarawickrama and Hunt (2007)
Taipei, China	All Sectors	1960–1984	-0.25	Holtedahl and Joutz (2004)
Taipei, China	Residential	1955–1996	-0.15	Holtedahl and Joutz (2004)
Thailand	All Sectors	1960–1984	-0.725	Ang (1988)

continued on next page.

Table A8.1.2 continued.

Table A 8.1.2 Sources of Estimates of Price Elasticity of Electricity Demand				
Country (Region)	Sector	Time Period	Estimates	Citation
Non-Asian Countries				
Costa Rica	Residential	–	–0.6	Cited in Westley (1992)
Egypt	All Sectors	1960–1981	–0.517	Abdel-Khalek (1988)
Ghana	Residential	1960–1977	–0.2	Glapke and Fazzolare (1985)
Ghana	Industrial and commercial	1960–1977	–0.46	Glapke and Fazzolare (1985)
Greece	Residential	1986–1999	–0.41	Hondroyiannis (2004)
Greece	Residential	1961–1986	–0.29 ^a	Donatos and Mergos (1991)
Ivory Coast	Residential	1960–1977	–0.78	Glapke and Fazzolare (1985)
Ivory Coast	Industrial and commercial	1960–1977	–0.66	Glapke and Fazzolare (1985)
Jamaica	Small industry	1970–1986	–0.43	Ramcharran (1990)
Jamaica	Large industry	1970–1986	–0.52	Ramcharran (1990)
Mexico (six regions)	Residential	1962–1979	–0.123 ^a	Berndt and Samaniego (1983)
Mexico (nationwide)	Residential	1962–1979	–0.81	Berndt and Samaniego (1983)
Namibia	All Sectors	1980–2002	–0.298	De Vita, Endresen, and Hunt (2006)
Nigeria	Residential	1960–1977	–0.31	Glapke and Fazzolare (1985)
Nigeria	Industrial and commercial	1960–1977	–0.67	Glapke and Fazzolare (1985)
Paraguay	Residential	–	–0.63	Cited in Westley (1992)
South Africa	Residential	1978–2005	–0.04	Ziramba (2008)

– = not specified.

^a Average is taken when multiple estimates due to different model specifications are available from the study.

Appendix 8.2 Electricity Demand Forecasting in the Philippines

The Manila Electric Company (MERALCO) is the largest distributor of electricity in the Philippines. Its methods for short-term demand forecasting for both electrical energy and power provide a relatively good practice example.

MERALCO has used four demand models for short-term forecasting: for residential energy demand; commercial energy demand; industrial energy demand; and peak load. All the coefficients in the models presented below meet the standard statistical significance requirements, but the details are suppressed for brevity. Economic growth figures are obtained from forecasts of government agencies and private research institutions. Projected customer numbers are based on population growth forecasts while real price projections are based on trend analysis.

Residential demand model

$$\ln Q_r = 3.38 + 0.48 \ln \left(\frac{GNP}{n} \right) - 0.43 \ln P_r + 1.03 \ln R_{cust} - 1.15\% \text{ Loss}$$

where

Q_r = billed residential sales

GNP/n = real gross national product per capita (using GNP deflator, base 1985, P18,257 for 2011)

P_r = real residential price of electricity (indexed to the consumer price index in Metro Manila, P1.4/kWh for 2011)

R_{cust} = number of residential customers in millions (4.418 in 2011)

$\%Loss$ = percentage distribution losses (0.89 in 2011)

By substituting the 2011 values for the explanatory variables in the residential demand equation, residential electricity demand for 2011 is projected at:

$$Q_{r2011} = 5,762,998.3 \text{ GWh}$$

Commercial demand model

$$\ln q_c = -9.722 + 0.757 \ln GNP - 0.06 \ln P_c + 0.656 \ln CC_{cust} - 1\% S_{Loss} - 0.092 PC_{crisis}$$

where

Q_c = billed commercial sales

GNP = gross national product in million Pesos in 1985 prices

P_c = real price/kWh of commercial electricity (using GNP deflator)

CCust = number of commercial customers

SLoss = system losses

PCrisis = dummy for power crisis of 1990–1993 (1 for crisis years, 0 otherwise)

With the last variable taking on zero value, GNP = 1,704,678, P_c = 1.7393/kWh, CCust = 472,760, SLoss = 0.089, the forecast commercial sales in 2011 is:

$$Q_{c2011} = 14,609.39 \text{ GWh}$$

Industrial demand

$$Q_i = 695.0 + 10.83IND - 575P_i + 0.193ICust - 549.4PCrisis$$

where

Q_i = billed industrial sales

IND = real industrial gross value added, in Pesos billion

P_i = real price/kWh to industry (using GNP deflator)

ICust = number of industrial customers

PCrisis = dummy for power crisis of 1990–1993 (1 for crisis years, 0 otherwise)

By substituting the 2011 values (IND = 540.7, P_i = 1.7017, ICust = 12,129, PCrisis = 0) in the above equation, the industrial electricity demand in 2011 is forecast to be:

$$Q_{i2011} = 7,913.2 \text{ GWh}$$

Total Demand in 2011:

$$Q_{T2011} = Q_{r2011} + Q_{c2011} + Q_{i2011}$$

$$Q_{T2011} = 5,785,520.9 \text{ GWh}$$

Peak Load

$$\ln PEAK = -0.821 + 0.971 \ln GNP + 0.291 \ln TCus - 0.077 LDROP + 0.051 ELNINO$$

where

PEAK = utility system peak demand

GNP = gross national product in billion Pesos

LDROP = dummy for massive load drops, 1990 and 1993

TCust = total number of customers, in thousands

ELNINO = dummy for weather phenomenon, 1998

Substituting the 2011 values (GNP = 1,704.5, LDROP = 0, TCust = 4,901.8, ELNINO = 0), the peak load in 2011 is predicted to be:

$$\text{PEAK}_{2011} = 7,165.0 \text{ MW}$$

Source: ADB staff estimates based on MERALCO methodologies.

9. Economic Analysis of Power Generation and Transmission Projects

9.1 Introduction

Following the general principles discussed in Chapter 8, this chapter presents two case studies based on actual projects. The analysis keeps the basic project data but simplifies a few issues for ease of exposition. The first of these case studies is a regional power project involving Lao People's Democratic Republic (Lao PDR) and Thailand and the basic analysis largely follows the original appraisal. The project is an example of a regional project that creates gains for more than one participating economy and the analysis here applies the modifications to economic analysis required for regional projects. The principles involved are set out before the analysis of the project itself.

The second case is a transmission line project from Viet Nam which is assessed as part of a wider power investment program. It extends the original economic analysis by:

- (i) applying the conceptual approaches described in Chapter 8,
- (ii) applying a more detailed and disaggregated set of conversion factors to move from financial to economic values, and
- (iii) conducting distribution analysis on the first-round effects of the project.

9.2 Economic Assessment of Regional Projects

The key aspect of any regional project is that it is intended to generate benefits for the participating countries that would not materialize if

they were to act independently by investing the same funds in national projects. Appraisals of regional projects should be able to identify these additional regional benefits and in appraising such projects it is necessary to modify the methodology used conventionally in the economic analysis of national projects (see Adhikari and Weiss 1999). In the regional context, it is necessary to estimate the net economic benefit to the region as a whole and the net gains to each participating country. This requires the calculation of the economic internal rate of return (EIRR) and net present value (NPV) both for the region and individual countries. The regional NPV gives the total change of welfare gains for the group of participating countries and this must be equal to or greater than, the sum of the national economic NPVs.

To justify treating a project as regional requires that it create benefits that would not be available to equivalent national projects located in the participating countries. The mechanisms for creating such benefits will vary between projects, but will be based on a variant of one or more of the following effects:

- (i) generation of additional funds through the attraction of external funding that would not be forthcoming for nationally-based projects,
- (ii) capture of economies of scale and efficiency gains from sub-regional specialization as larger enterprises selling in a regional rather than a national market can produce at lower unit costs, and
- (iii) creation of external effects or regional public goods that accrue outside the boundaries of one individual country.

Examples of regional cooperation projects include power projects, but also cover

- (i) cross-border road projects that combine transport links with improved transit and customs facilities to expedite regional trade and travel,
- (ii) tourism circuit projects that link countries as tourist destinations through booking arrangements and visa waivers, and
- (iii) infectious disease control projects to prevent the spread of disease across national borders.

In assessing a regional project, the following issues need to be addressed:

- (i) Analysis of a regional project can be started with the financial analysis if the project is a revenue-generating project. In regional

projects, shareholders will be from the participating countries and possibly from outside the region. Profits to extra-regional shareholders are treated as outflows from the region and not part of the regional returns from a project. Similar to national projects, the outputs of a regional project can be separated for non-incremental and incremental outputs in the case of large or non-marginal projects. If the project output is small compared to the total regional output, the sales revenue (subjected to appropriate economic pricing) will be the benefit of the project. Where regional projects are non-marginal in the sense of altering consumer prices, the analysis requires adding surplus changes to the sales revenues in estimating benefits. The non-incremental benefits and incremental benefits in each country will be the values of resource cost savings and willingness to pay (WTP), respectively. Moreover, where sales take place in more than one country, the WTP in the different participating countries should be estimated separately.

- (ii) Conversion of financial prices to economic prices needs to take account of the specific country circumstances. The two most common adjustments are through the use of national conversion factors (CFs) for unskilled labor (in labor-surplus economies), and foreign exchange in economies with disequilibrium exchange rates and significant trade taxes and controls. Individual sector or commodity conversion factors may be required for subsidized commodities (like water, power, or transport). For regional projects with no cross-border labor migration, national labor CFs will be relevant. However, where migrant workers from within the region are employed by the project the relevant economic cost for the region will be their opportunity cost from the country of origin, not the country where the project is located. If wages are the same in the two countries, the CF from the country of origin can be used. Where wages are higher in the country where the project is located than in the country of origin, the appropriate CF will be project-specific, given as:

$$\text{CF (labor)} = (\text{opportunity cost in country of origin} + \text{costs of migration}) / \text{project wage}.$$

In estimating the full regional effect of such a project it will be necessary to distinguish between migrant and local workers

since the difference between the wage and opportunity cost of labor will be a gain to different participating countries depending on whether migrant or local labor is used.

- (iii) For any regional project it is easier to use a common currency (normally the US dollar) rather than any country-specific currency. However, if any of the participating countries has a shadow exchange rate factor (SERF) that differs from unity this implies that the local currency benefits of additional dollars are greater or less than the prevailing exchange rate suggests. If the SERF is the same for all participating countries then a single SERF value is used consistently to adjust foreign exchange benefits and costs. However, it will still be necessary to identify which country's central bank is buying or selling the foreign currency since the premium (SERF-1) reflects a gain/loss to the country whose foreign exchange reserves have changed. Where SERFs are different in the participating countries, there is a need for a country disaggregation. Since trade taxes and controls are now relatively low in most countries this adjustment is most obviously relevant where currencies of participating countries are under or overvalued in real terms, which implies that the future value of dollars in these countries will rise at a rate above national inflation (where the national currency is overvalued) or at a lower rate than national inflation (where it is undervalued). This is a difficult forecasting estimate to make but is required since foreign exchange risk is built into regional projects and benefits must be converted into different currencies.
- (iv) Any input subsidies in one country (for example, diesel sold in one country at below the world price equivalent) will benefit not just consumers or users in that country but also those from the other participating country (for example, electricity users who use imported electricity produced using subsidized diesel). This must be reflected in the regional distributional analysis and will be a transfer from the government of the subsidizing country to groups in the other participating countries.
- (v) The economic discount rate in project analysis is used typically to reflect the opportunity cost of capital in an economy. In principle, it is possible that there may be differing economic discount rates in different participating economies, since resource endowments, policy environment, and tax regimes

will differ. However, as barriers to capital flows are lowered and tax regimes are harmonized the expectation is that divergences between potential returns to investment in different national markets will narrow. Hence, in practice, it is normally adequate to apply a single rate to a regional project reflecting the cost of capital in all countries. It is generally understood that regional appraisals should be carried out at the single predetermined rate (such as 12% in ADB projects), while recognizing that this may imply some simplification.

- (vi) Regional distributional analysis follows the standard procedure of distributional analysis of national projects with the difference that there is a distinction not just between stakeholder groups, but between their countries of location. Changes in income can be allocated to different groups following the identity

$$NPV_{econ} = NPV_{fin} + (NPV_{econ} - NPV_{fin})$$

where econ and fin refer to income flows at economic and financial prices, respectively.

To apply this approach requires that the income changes for different economies from a regional project be estimated at two stages.

First, it is necessary to establish the gainers and losers from the operations of the project valued at financial prices. At this stage the financing structure of the project, that is, its loan and equity mix must be identified, and income flows to equity investors and lenders must be estimated. Any project-specific finance with a concessional element, in the sense that capital inflows exceed outflows will be a benefit for the countries concerned. At this stage, the analysis addresses the question of who gains or loses from the financial operations of the project.

Second, it is necessary to consider how the externalities and distortions (in the sense of a divergence between economic and financial prices) associated with the project alter the allocation of income from that reflected in the financial calculations. In the presence of externalities and distortions, financial prices by definition do not give the full economic picture, and some groups must gain where economic costs are below financial costs and similarly where economic benefits exceed benefits at financial prices. Correspondingly, someone must lose where economic costs exceed financial ones and where economic benefits are below benefits at financial prices. Hence, at this stage the analysis picks

up the gainers and losers from externalities and distortions. This can be potentially complex, for example, where users of a cross-border road project come from different countries and where any environmental impact (for example, from a hydro dam or tourism project) is spread throughout the region. Additional surveys that would not be needed for national projects may be required to allow estimates of differential impacts between countries.

9.3 Case Study: Nam Theun 2 Hydroelectric Project

The case study illustrates the application of economic analysis methodology for an actual regional energy project involving two countries. The case study is based on the 1,000-MW Nam Theun 2 (NT2) hydroelectric project located in the Lao PDR and selling most of the generated electricity (around 97%) to Thailand.

The NT2 project was developed by a private company, Nam Theun 2 Power Company (NTPC), which is owned by the Government of Lao PDR (GOL, 25%), Electricité de France International (EDF, 35%), and two Thai companies, Electricity Generating Public Company (25%) and Italian-Thai Development Public Company Ltd. (15%). Upon commercial operation, NTPC will sell power at pre-negotiated prices to the Electricity Generating Authority of Thailand (EGAT) and to Electricité du Laos (EdL). While NTPC will operate and maintain the NT2 facility, EGAT will have full dispatch control of the electricity going to Thailand.

The project construction period was around 5 years, commencing in 2005, with predevelopment costs starting in 2004. Project commissioning was expected in 2010. The economic impact of the project is evaluated from the regional perspective following the principles set out above. All aspects of the original appraisal have been modified to simplify the exposition.

From the perspective of Lao PDR, the project's objective is to develop hydroelectric power as a key source of foreign exchange and, secondly, to devote a small part of the output to domestic consumers as a low-cost source of supply. Lao PDR is well-positioned to develop hydroelectric

energy because of its abundant water resource and physical location between rapidly growing economies.

For Thailand, demand for power had been growing rapidly and at the time the project was planned, large capacity in the order of 1,500 MW and 9,500GWh per year were estimated to be required up to 2010 (see Table 9.1). The NT2 project will supply part of this and help diversify Thailand's power supply and in particular to reduce dependence on natural gas as an energy source.

From a regional perspective, it is potentially efficient for Lao PDR, through this project, to make use of its comparative advantage in natural resource availability, while helping Thailand meet its growing power demand. The trend toward closer regional cooperation and regional grid interconnections opens up opportunities for Lao PDR to develop hydroelectric power projects—otherwise not viable for the domestic market—to serve the rapidly growing regional power market.

Recognizing institutional capacity constraints, the project was developed as a public-private partnership (PPP) under a build-own-operate-transfer scheme. The NT2 facilities will be transferred to the government free of charge at the end of the concession period of 31 years. The advantages put forward for the private sector undertaking the project were: (i) efficient, effective, and on-target implementation; (ii) access to global capital; and (iii) access to state-of-the-art technology. The challenge for the government and NTPC is to maximize benefits while ensuring that potential adverse social and environmental impacts of the project are fully addressed through a detailed program of mitigation, compensation, rehabilitation, and offset measures.

9.3.1 Demand Analysis

Demand for electricity in Thailand has been growing strongly with the recovery of economic growth after the Asian financial crisis of the late 1990s. Table 9.1 summarizes the two separate “Medium Economic Growth” load forecasts for Thailand that formed the basis for planning the project, which were presented in the Power Development Plans (PDP) for 2003 and 2004.¹

¹ The demand forecasts are based on income elasticity and GDP growth estimates.

Table 9.1 Thailand: Load Forecasts

Source	Year	Net	Load	Maximum	Reserve	Average Annual	
		Generation (GWh)	Factor (%)	Demand (MW)	Margin (%)	(MW)	(GWh)
Thai PDP (FY 2003)	2003	114,754	73	17,843	35		
	2005	130,232	73	20,295	25	1,226	7,739
	2010	178,079	73	27,711	17	1,483	9,569
	2015	236,364	73	36,754	15	1,809	11,657
Thai PDP (FY 2004)	2003	116,743	74	18,121	(n/a)		
	2005	136,784	74	21,143	(n/a)	1,511	10,020
	2010	193,530	75	29,308	(n/a)	1,633	11,349
	2015	265,788	75	40,478	(n/a)	2,234	14,452

FY = fiscal year, GWh = gigawatt-hour, MW = megawatt, n/a = not available, PDP = power development plan.
Source: Thailand Load Forecast Subcommittee, August 2002 and January 2004.

The Lao PDR electricity supply system is small in comparison with the Thai system. It consists of four grids, which are not interconnected. When the project was planned, demand was characterized by relatively low per capita consumption (211/kWh/year) and a low electrification rate (40%) compared to other countries in the region. Historically, domestic consumption was small in relation to total production and exports; however, this situation changed over the 1990s with imports increasing as a share of total domestic production, and the share of exports declining. The NT2 project was designed to reverse this and to increase exports by at least 5,354GWh annually, while also generating an additional 200-300GWh for domestic use.

9.3.2 Least-Cost Analysis

For Thailand, the World Bank and EGAT conducted an evaluation with the NT2 project competing for a place in the sector expansion plan along with fossil-based alternatives—oil-fired steam, coal-fired steam, gas-fired combined cycle gas turbines (CCGT)—and reconditioned thermal units otherwise scheduled for retirement over the 2004–2014 investment period.² The evaluation found that NT2 was the cheapest alternative

² World Bank, 2004. Nam Theun 2 Project Economics Interim Summary Report.

among all available options. Without the NT2 project, domestic CCGT capacity was the next best alternative. The study found that by implementing NT2 as against the CCGT option, the accumulated present value (at a 10% discount rate) of real resource savings over the study period amounted to \$277 million at 2003 prices.

Similarly, the Power System Development Plan (PSDP) for Lao PDR found that the NT2 project was the least cost among 33 hydro projects and two thermal projects, based on mid-2003 prices and a discount factor of 10% (Table 9.2). The NT2 project's expected generation cost of \$0.016/kWh was about two-thirds of the cost of the next least-cost project—a 105-MW unit extension to Theun Hinboun Hydropower (THH). While the PSDP identified other smaller sites that could be developed to meet the local load, the evaluation concluded that they were not cost-effective, when compared with the NT2 project.

Table 9.2 Lao PDR: PSDP Hydropower Project Ranking

Rank	Project	Project Type	Installed Capacity (MW)	Annual Output (GWh)	Weighted Cost (\$/kWh)
1	Nam Theun 2	Storage/transfer	1,074	5,922	0.016
2	Theun Hinboun Extension	Storage/transfer	105	686+	0.024
3	Thakho	R-of-R/Mekong	30	214	0.026
4	Nam Mo	Storage	125	603	0.027
5	Xe Kaman 3	Storage	250	1,369	0.028

GWh = gigawatt-hour, kWh = kilowatt-hour, Lao PDR = Lao People's Democratic Republic, MW = megawatt, PSDP = Power System Development Plan, R-of-R = run of river.

Source: Meritec Ltd. With Laymeyer GmbH, Power System Development Plan for Lao PDR. August 2004.

9.3.3 Project Costs

Project costs include development and pre-operating expense, construction costs, operating and maintenance (O&M) expenses, and the dedicated transmission line in Thailand funded by EGAT (Table 9.3).

The total project investment cost in financial terms, excluding the costs of project financing, interest during construction, and price contingencies, was estimated at \$1,036.2 million at constant 2004 prices. Annual operating costs, including environmental and social

costs, NTPC administration, and O&M costs (including O&M of the Thai transmission line) were estimated to be at \$16.83–23.08 million. In the pre-operating phase of the NT2 in 2009, the operating cost, without O&M of the transmission line, was estimated at \$2.36 million. O&M costs of the transmission line (1% of the capital expenditure for the line) and the substations (2%) were estimated at \$1.98 million per year. System losses in Thailand are excluded from the analysis since they are common in the with- and without-project cases on the assumption that the NT2 project would not change the existing system losses in Thailand. However, losses on the dedicated NT2 project transmission line (assumed at 1% per year) are incremental to the existing losses, and are therefore incorporated in the analysis.

Investment and O&M costs in financial prices are adjusted to reflect the economic resource cost of project inputs in terms of the domestic price numeraire. Costs are allocated into traded goods, non-traded goods, foreign skilled labor, local skilled labor, local unskilled labor, fuel, and transfer payments, and are adjusted by the appropriate conversion factors. Non-traded goods and skilled labor are assumed to reflect their economic prices, hence, no conversion is applied. Traded costs (including fuel) are multiplied by the shadow exchange rate factor (SERF), and unskilled labor costs are multiplied by the shadow wage rate factor (SWRF). Transfer payments and price contingencies are excluded from the economic analysis. The original analysis used a single SERF of 1.05 for both Lao PDR and Thailand, but here for illustration different SERFs of 1.08 for Lao PDR and 1.0 for Thailand are applied. The SWRF for Lao PDR is based on an estimate of the average income (cash and non-cash income) in the project area (Kip15,010/day) and an estimate of project wage for unskilled labor (Kip21,200/day).³ This gives a SWRF of 0.71. Application of these conversion factors to the financial costs gives an overall economic cost of \$1,042.5 .5 million (Table 9.3).

9.3.4 Project Benefits

Project benefits include incremental benefits (pertaining to project sales to Thailand, valued at WTP and non-incremental benefits (pertaining to domestic sales, valued at resource cost savings).

³ The case study assumes that all unskilled labor comes from Lao PDR. In general, if migrant labor from within the region is involved, the opportunity cost of labor in the country of origin should be used for the relevant portion of the labor component.

Table 9.3 Investment Costs

	Summary of Costs by Year (US\$, million)							
	Total	2004	2005	2006	2007	2008	2009	2010
Investment Costs, constant 2004 Prices, excluding price contingencies (Financial Prices)								
A. Pre-operating costs	218.8	23.0	71.6	21.7	28.5	20.2	53.8	–
B. Construction cost	682.4	50.0	140.8	177.2	172.9	102.2	39.2	–
C. Thai transmission	135.0	1.4	6.3	6.1	28.8	69.2	15.6	7.4
Total	1,036.2	74.4	218.7	205.1	230.2	191.7	108.7	7.4
Investment Costs, constant 2004 prices (Economic prices)								
A. Pre-operating costs	220.4	23.2	72.1	21.9	28.7	20.4	54.2	–
B. Construction cost	687.2	50.4	141.8	178.5	174.1	102.9	39.5	–
C. Thai transmission	134.9	1.4	6.3	6.1	28.8	69.2	15.6	7.4
Total	1,042.5	74.9	220.2	206.5	231.6	192.5	109.3	7.4

Source: ADB (2005a).

A: Incremental Benefits: Thailand

Project output sales to Thailand will go to the national grid. Given the rapid demand growth in the Thai market due to rising incomes, it is assumed that the load growth for all customer segments is incremental consumption. Therefore NT2 sales to Thailand—representing 97% of sales—are assumed to be incremental. This situation corresponds to the benefits depicted in Figure 8.3 so that with rising power demand due to income growth we can apply equation (5) from Chapter 8.⁴

Incremental benefits of electricity to Thailand consist of the sales revenue of EGAT and the consumer surplus. Sales revenue is the product of the incremental sales in GWh (less 1% of transmission line losses) and the average retail tariff of \$0.0535/kWh. Note that the retail tariff is higher than the levelized power purchasing agreement (PPA) tariff negotiated

⁴ The price elasticity of demand for electricity in Thailand was obtained from Ang (1988) who applied two log linear equations using national level data covering all the sectors from 1960 to 1984. The first equation used price and GDP per capita as independent variables and the second equation used lagged electricity consumption in addition to price and GDP per capita. The long-run elasticities from these two equations were estimated to be -0.64 and -0.81 . The average of these two estimates (-0.725) was used here in the application of equation (5) from Chapter 8.

with NTPC of \$0.039/kWh at constant 2004 prices.⁵ The margin will accrue to EGAT and forms part of the benefits to Thailand, which in principle could be passed on to consumers at a later date or used for reinvestment and expansion.

The aggregate annual incremental electricity (primary and secondary electricity) sales in Thailand are estimated at 808 GWh and 5,438 GWh in 2009 and 2010, respectively and 5,354 GWh for the rest of the project period.

Consumer surplus (CS) is calculated using equation (5) from Chapter 8:

$$CS = 0.5[P_E (\Delta Q)^2 / (e_d Q_1)].$$

where P_E is the retail tariff of \$0.0535/kWh, ΔQ is incremental sales (less transmission line losses), e_d is equal to -0.725 which is taken as the average price elasticity of demand for power in Thailand, and Q_1 is the forecast net generation for Thailand for 2009 based on the EGAT forecast in 2004 (see Table 9.4).

To illustrate for year 2010:

$$\begin{aligned} \text{Consumer surplus} &= 0.5 \times \frac{(\text{average retail tariff} \times \text{project output}^2)}{(\text{price elasticity of demand} \times \text{without-} \\ &\quad \text{project output})} \\ &= 0.5 \times \frac{(0.0535 \times 5,384^2)}{(0.725 \times 193,530)} \\ &= \$5.5 \text{ million} \end{aligned}$$

B: Non-incremental Benefits: Lao PDR

The electricity system in Lao PDR is comprised of four major unconnected grids. The CR2 grid serves the region in which the NT2 project is located. The primary source of electricity for the area is imports from Thailand, both directly to some large customers, and indirectly through sales to local area grids. Direct cross-border sales take place between EGAT and EdL for larger grid off-take while the Thailand Provincial Electricity Authority (PEA) sells to large industrial customers and town grids at both medium and low voltage levels. Once NT2 electricity is available both these two sources will be replaced by the remaining 3% of sales

⁵ Sales to Thailand are valued at the levelized PPA tariff, at constant 2004 prices, calculated by dividing the present value of the revenues by the present value of GWh sales (at a 12% discount rate).

from the NT2 project. Therefore, all Lao purchases from the NT2 project are defined as non-incremental output and are valued at resource cost savings.

Non-incremental benefits of electricity to Lao PDR are valued based on the economic cost of purchase of electricity from Thailand without the project. Lao PDR grid customers would obtain substitute electricity from Thailand, at a price of \$0.065/kWh. This price is estimated based on the generation cost plus the cost of wheeling (\$0.005/kWh) that power to the Lao PDR grid. The estimated generation cost is based on the cost of energy (\$0.026/kWh) and a capacity cost (\$0.034/kWh). The large customers close to the Thai border and smaller grids may obtain substitutes directly from the PEA. PEA sells directly to these larger customers at its normal rates for medium and large general service customers, at \$0.062/kWh and \$0.068/kWh, respectively. As these are foreign exchange costs incurred by Lao PDR they must be converted to economic prices by multiplication by the SERF for Lao PDR of 1.08.

Table 9.4 summarizes the weighted average avoided cost used to estimate non-incremental benefits, with a 60% weight given to the grid customers, 20% to the cost of direct imports from PEA at medium voltage, and 20% to the cost of direct imports from PEA at lower voltage. The weighted average avoided cost is thus estimated at \$0.065/kWh, and the economic price of the resource cost savings is \$0.070/kWh.

Table 9.4 Non-incremental Consumption: Weighted Average Avoided Costs

	Weight ^a	Financial Cost	Conversion factor	Economic Price
Lao PDR avoided cost: primary (incl. wheeling)	60%	0.065	1.08	0.070
PEA Border Sales: MV	20%	0.062	1.08	0.067
PEA Border Sales: LV	20%	0.068	1.08	0.073
Weighted average value of Lao PDR avoided cost =		0.065		0.070

Lao PDR = Lao People's Democratic Republic, LV = low voltage, MV = medium voltage, PEA = Provincial Electricity Authority of Thailand.

^a Weight represents the percent of total energy use supplied by this resource in the without-project case. Notes:

Lao PDR: based on national allocation to three sources of supply:

60% valued at the avoided cost of firm imports (Thai avoided cost + wheeling charge of \$0.005/kWh).

20% valued at the PEA tariff for current cross-border sales to MV customers (69 kilovolts [kV]).

20% valued at the PEA tariff for current cross-border sales to LV network (11kV).

Source: ADB (2005a).

The operation of the NT2 project has the additional effect of displacing generation of 275 GWh from the existing Theun Hinboun IPP hydro project (THH), which shares the catchment area with the NT2 project. Conceptually this production loss is similar to a power outage and hence corresponds with the situation depicted in Chapter 8 Figure 8.5. The total loss in benefit is equal to the area under the demand curve bounded by the production loss. However, since consumers no longer have to pay for the 275 GWh of electricity, the loss in sales revenue will be a benefit for the Lao economy. That is, consumers can spend that amount on purchasing other goods or services. Therefore, the real loss from this reduced production is the loss of consumer surplus (area abc in Figure 8.5). The loss of consumer surplus is considered as a cost to the Lao PDR economy and it can be estimated using equation (5) of Chapter 8. In the absence of any specific price elasticity estimates for Lao PDR the average price elasticity for Asian developing countries (-0.43) is used for estimating consumer surplus.⁶

In applying equation (5) of Chapter 8, the electricity tariff in Lao PDR is taken as the weighted average cost from THH of \$0.024/kWh. Total generation without the project (Q_1 in equation [5] of Chapter 8) is annual generation of 686 GWh with the project plus the loss of 275 GWh. Putting these values into equation (5) of Chapter 8 gives:

$$CS = 0.5 * \{ (0.024 * (275)^2) / (0.43 * 686 + 275) \}$$

Thus, the loss in consumer surplus to Lao PDR is estimated at \$5.1 million. This is shown as a negative benefit item in Table 9.5.

9.3.5 Regional Cost-Benefit Analysis

One of the major assumptions in regional economic analysis is that costs and benefits can be aggregated to estimate regional project indicators. From the regional perspective, the project economic cost includes all the costs in the two countries, that is, the pre-development and construction costs for the NT2 project, plus the cost of the associated transmission line in Thailand, and the operating and maintenance costs of both NT2 and the Thai transmission line. Benefits include sales of energy to Thailand (incremental benefits) and to Lao PDR (non-incremental

⁶ Sensitivity analysis using the maximum and minimum values of the elasticity show that regional and Lao PDR economic indicators do not change significantly.

benefits), valued according to the estimation procedures discussed. The NT2 project will result in an annual reduction of 275 GWh for the THH project, which shares the catchments' area with the NT2 project. It is a real resource cost and therefore included as a cost (or disbenefit) of the project. The NT2 project will also reduce Thai exports to Lao PDR by approximately 200-300 GWh per year; however the Thai energy sector can readily absorb all power previously exported to Lao PDR so there is no cost involved due to lost exports. It should be noted that this implies the assumption that the export price and domestic WTP for power in Thailand are equal.

Since the project is examined from the regional perspective—that is, net benefits are those going to both Lao PDR and Thailand—it is necessary to combine data from the financial and economic analyses. This is because outflows from the region in the form of dividends to foreign investors (who have 35% of the equity) are a loss to the region and must be deducted from net benefits. In order to calculate dividend payments, however, it is necessary to establish the financial returns to the project. Full data on the financing plan of the project are not available and here the simplifying assumption is made that total project capital costs are funded exclusively by equity. Further, the additional investment cost of the transmission line in Thailand is assumed to be covered by EGAT and not by the NT2 project. This is shown as a cost to EGAT in the distribution analysis. For simplicity, the operating costs of the transmission line are assumed to be covered by the project rather than EGAT, but as these are small this assumption will not have a significant impact on the distribution results.

For the financial analysis, the difference between project sales revenue and capital and operating cost at financial prices (with the capital cost of the transmission line excluded) gives net financial benefit. From the original project data 48% of this net benefit figure goes to Lao PDR as royalty and the remainder is available for distribution as dividends. The share accruing to foreign investors is treated as an outflow from the region, since even if it is not remitted immediately it can be at a future date. This approach implicitly assumes that the foreign investment inflow that finances the 35% equity stake in the project is not incremental to the region and would have been forthcoming in the absence of this project. However the dividends that accrue to this equity investment are in excess of the assumed opportunity cost of these funds of 12% and hence represent additional profits that would not have left the region if

the funds had been invested in an alternative project (at a 12% internal rate of return).

The SERF of 1.08 reflecting a misalignment of the Kip with the US dollar (and by implication the Thai Baht) is applied to foreign exchange transactions by the project outside the region. Hence the traded components of capital and operating costs and the value of dividends accruing to foreign investors are multiplied by 1.08. Transactions within the region between Lao PDR and Thailand are not adjusted in the regional economic analysis as any exchange rate misalignment of the Baht and the Kip affects intra-regional distribution, not the value of absolute net benefits. The premium of foreign exchange in Lao PDR is allowed for, however, when the intra-regional distributional effects of the project are assessed.

Costs resulting from negative environmental or social impacts are included. This is because mitigatory expenditures and compensation costs of resettlement are already incorporated in the project's capital and operating costs. Specifically, a total of \$130 million (at current market prices) has been allocated to environmental and social programs (including \$49 million for pre-operations programs, \$22 million for loss of future eco-tourism potential, and \$59 million for annual operating costs related to environmental and social programs). The assumption used here is that these environmental improvement, mitigation and compensation programs are sufficient to prevent significant social and environmental costs.

Table 9.5 presents the details of the cost and benefit streams for the region. The economic NPV is estimated at \$389.4 million and the EIRR is 17.5%. The average incremental economic cost of electricity is \$0.039/kWh.

9.3.6 Distribution within the Region

The analysis from the perspective of the project as a whole indicates that the NT2 project is economically viable. However, the project must also be economically viable for both participating countries. The key parameter that influences the distribution of intra-regional benefits is the negotiated export price for sales to EGAT. As discussed above, the income gains

Year		Table 9.5 Regional Economic Analysis										Net Benefits (US\$, Million)												
		Electricity Consumption (GWh)					Benefits (US\$, Million)						Costs (US\$, Million)											
		Sales		Losses			Consumed		Revenue from		Incremental (Thailand CS)		Non-incremental (Lao PDR)		THH Loss (Lao CS)		Total Benefits		Capital		O&M		Dividends	
		Lao PDR	Thailand	Thailand T/L	Losses	THH Losses	Total Consumed	Revenue from Thailand	Incremental (Thailand CS)	Non-incremental (Lao PDR)	THH Loss (Lao CS)	Total Benefits	Capital	O&M	Dividends	Total Costs	Net Benefits (US\$, Million)							
2004	-	-	-	-	-	-	-	-	-	-	-	-	74.9	-	-	74.9	(74.9)							
2005	-	-	-	-	-	-	-	-	-	-	-	-	220.2	-	-	220.2	(220.2)							
2006	-	-	-	-	-	-	-	-	-	-	-	-	206.5	-	-	206.5	(206.5)							
2007	-	-	-	-	-	-	-	-	-	-	-	-	231.6	-	-	231.6	(231.6)							
2008	-	-	-	-	-	-	-	-	-	-	-	-	192.5	-	-	192.5	(192.5)							
2009	24	808	(8)	(275)	(275)	550	42.8	0.1	1.7	-	-	44.6	109.3	4.4	-	113.7	(69.0)							
2010	163	5,438	(54)	(275)	(275)	5,271	288.0	5.5	11.4	(5.1)	(5.1)	299.8	7.4	18.3	-	25.7	274.1							
2011	175	5,354	(54)	(275)	(275)	5,200	283.6	5.4	12.3	(5.1)	(5.1)	296.1	-	18.3	-	18.3	277.8							
2012	190	5,354	(54)	(275)	(275)	5,215	283.6	5.4	13.3	(5.1)	(5.1)	297.1	-	18.3	-	18.3	278.8							
2013	200	5,354	(54)	(275)	(275)	5,225	283.6	5.4	14.0	(5.1)	(5.1)	297.8	-	18.3	-	18.3	279.5							
2014	200	5,354	(54)	(275)	(275)	5,225	283.6	5.4	14.0	(5.1)	(5.1)	297.8	-	17.6	-	17.6	280.3							
2015	200	5,354	(54)	(275)	(275)	5,225	283.6	5.4	14.0	(5.1)	(5.1)	297.8	-	16.9	-	16.9	280.9							
2016	200	5,354	(54)	(275)	(275)	5,225	283.6	5.4	14.0	(5.1)	(5.1)	297.8	-	16.9	-	16.9	280.9							
2017	200	5,354	(54)	(275)	(275)	5,225	283.6	5.4	14.0	(5.1)	(5.1)	297.8	-	16.9	-	16.9	280.9							
2018	200	5,354	(54)	(275)	(275)	5,225	283.6	5.4	14.0	(5.1)	(5.1)	297.8	-	23.2	-	23.2	274.6							
2019	200	5,354	(54)	(275)	(275)	5,225	283.6	5.4	14.0	(5.1)	(5.1)	297.8	-	23.2	-	23.2	274.6							
2020	200	5,354	(54)	(275)	(275)	5,225	283.6	5.4	14.0	(5.1)	(5.1)	297.8	-	23.2	-	23.2	274.6							
2021	200	5,354	(54)	(275)	(275)	5,225	283.6	5.4	14.0	(5.1)	(5.1)	297.8	-	23.2	-	23.2	274.6							
2022	200	5,354	(54)	(275)	(275)	5,225	283.6	5.4	14.0	(5.1)	(5.1)	297.8	-	16.9	-	16.9	280.9							

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Table 9.5 continued.

Year	Electricity Consumption (GWh)										Benefits (US\$, Million)					Costs (US\$, Million)					Net Benefits (US\$, Million)
	Sales					THH Losses					Total Consumed	Revenue from Thailand	Incremental (Thai CS)	Non-incremental (Lao PDR)	THH Loss (Lao CS)	Total Benefits	Capital	O&M	Dividends	Total Costs	
	Lao PDR	Thailand	Thailand T/L	Losses	THH Losses	Total Consumed	Revenue from Thailand	Incremental (Thai CS)	Non-incremental (Lao PDR)	THH Loss (Lao CS)											
2023	200	5,354	(54)	(275)	5,225	283.6	5.4	14.0	(5.1)	297.8	-	16.9	-	16.9	280.9						
2024	200	5,354	(54)	(275)	5,225	283.6	5.4	14.0	(5.1)	297.8	-	16.9	-	16.9	280.9						
2025	200	5,354	(54)	(275)	5,225	283.6	5.4	14.0	(5.1)	297.8	-	16.9	-	16.9	280.9						
2026	200	5,354	(54)	(275)	5,225	283.6	5.4	14.0	(5.1)	297.8	-	16.9	-	16.9	280.9						
2027	200	5,354	(54)	(275)	5,225	283.6	5.4	14.0	(5.1)	297.8	-	16.9	-	16.9	280.9						
2028	200	5,354	(54)	(275)	5,225	283.6	5.4	14.0	(5.1)	297.8	-	16.9	-	16.9	280.9						
2029	200	5,354	(54)	(275)	5,225	283.6	5.4	14.0	(5.1)	297.8	-	16.9	-	16.9	280.9						
2030	200	5,354	(54)	(275)	5,225	283.6	5.4	14.0	(5.1)	297.8	-	16.9	-	16.9	280.9						
2031	200	5,354	(54)	(275)	5,225	283.6	5.4	14.0	(5.1)	297.8	-	23.2	-	23.2	274.6						
2032	200	5,354	(54)	(275)	5,225	283.6	5.4	14.0	(5.1)	297.8	-	23.2	-	23.2	274.6						
2033	200	5,354	(54)	(275)	5,225	283.6	5.4	14.0	(5.1)	297.8	-	23.2	-	23.2	274.6						
2034	200	5,354	(54)	(275)	5,225	283.6	5.4	14.0	(5.1)	297.8	-	23.2	1,186.32	1,209.60	(911.7)						
NPV	776	21,722		(1,232)	21,049	1,150.50	21.4	54.4	(20.4)	1,206.0	704.6	76.6	35.4	816.6	389.4						
EIRR																17.50%					
NPV/ kWh consumed																0.033	0.004	0.039	0.018	(AIEC)	

AIEC = average incremental economic cost, CS = consumer surplus, EIRR = economic internal rate of return, kWh = kilowatt-hour, Lao PDR = Lao People's Democratic Republic, NPV = net present value, O&M = operating and maintenance, THH = Theun Hinboun hydropower project, T/L = transmission line.
Source: ADB (2005a).

to the participating countries are determined by a combination of the financial effects of the project (dividend payments, taxes, and royalties) and the deviations between financial and economic prices.

Lao PDR is affected as follows:

- (i) The government of Lao PDR as an investor in NT2 gains its share (25%) of the dividends. It also gains the royalty payments negotiated as part of the project, which are 48% of net financial benefits and all of the tax payments made by the project on its operations. Sales to Thailand are valued at the levelized PPA tariff at constant 2004 prices.⁷ The transmission losses are not included in the analysis because the revenue to Lao PDR is based on total sales.
- (ii) Consumers in Lao PDR lose the consumer surplus due to the lower production from THH, which is included as a cost of the project. However it is assumed that the non-incremental benefits of avoided costs due to displaced power imports from Thailand are passed on fully to consumers, so they gain the reduction in cost due to the displacement of higher cost imports.
- (iii) Unskilled workers in Lao PDR obtain jobs at a wage above their opportunity cost and their net gain is determined by the difference between the project wage and their opportunity cost. Given the SWRF of 0.71, their net gain is 29% of the wage paid.
- (iv) The government of Lao PDR is treated as the beneficiary of the exchange rate misalignment. This is the conventional procedure on the assumption that misalignment is caused by taxes and that more foreign exchange will allow higher expenditure that will generate higher trade tax revenue for the government. This means that it gains 8% of the foreign exchange revenue of the project from sales to Thailand, but loses 8% of the dividend payments from the project to the Thai investors. As intraregional flows, gains to Lao PDR from the misalignment of the Baht and the Kip are matched by losses to Thailand of the same size and vice versa.

When sales to Thailand are valued at the base case levelized PPA tariff and adjusted by the SERF of 1.08, the economic NPV accruing to Lao PDR is \$178 million or approximately 46% of total net benefits to the

⁷ Levelized tariff is calculated by dividing the present value of the revenues by the present value of GWh sales (at a 12% discount rate).

region. This figure is around 8% of GDP for Lao PDR indicating that the project is clearly non-marginal.

Similarly, Thailand is affected as follows:

- (i) Consumers in Thailand gain the consumer surplus on sales from the project. Lost Thai exports to Lao PDR are not considered as a cost to the Thai economy because the quantity of electricity exported to Lao PDR without the project can be used within Thailand. If there is a difference in tariff charged in Lao PDR and Thailand, this may result in net resource transfer from one country to another. For example, if EGAT or PEA charges higher tariffs for exported electricity, compared to what they charge in Thailand, it may result in some loss to Thailand. Given that only 3% of the NT2 outputs are used to displace Thai exports, this potential loss is very small and is ignored here.
- (ii) EGAT gains the difference between the sales price to Thai consumers and the negotiated price it pays to the project. However EGAT meets all of the extra investment cost in transmission within Thailand. For simplicity the low transmission operating costs are included as part of operating cost and are not allocated to EGAT, The loss to Thailand created by the exchange rate misalignment is shown as a cost to EGAT, since without the misalignment it would have paid less Baht-equivalent to receive the power from the project.
- (iii) The Thai project investors who hold 40% of the equity receive 40% of the dividends declared by the project. As this is a dollar payment these investors gain from the exchange rate misalignment relative to Lao investors as they will receive dollars that are worth more than the exchange rate suggests.

The economic NPV for Thailand is \$212 million or 54% of the total net benefit to the region.

The key determinant of the distribution of gains between the two countries is the negotiated export price (reflected here by the levelized PPA tariff). If this is altered without changing the prices to final consumers in Thailand the intra-regional distribution alters without changing the total regional economic NPV.⁸ If the negotiated price is reduced, Lao PDR loses relative to Thailand and conversely, when it is increased, Lao

⁸ This assumption implies that any loss to Thailand created by a higher negotiated price reduces the surplus to EGAT, not consumer welfare, which remains unaffected as the power tariff is treated as constant.

PDR gains. Table 9.6 shows the distributional effect for the base case negotiated export price and variants of this price, while Figure 9.1 gives the summary position for different prices. It can be seen that at a price increase of 28% above the base case price, the gain to Thailand becomes negative, indicating that the return to the country is below the 12% discount rate, which is taken as reflecting the opportunity cost of the funds committed to the project. This 28% price rise is a switching value price for the project since at this level the project will not be attractive for Thailand.

	Financial Present Values	Conversion Factors	Economic Present Values	Difference (EPV-FPV)	Distribution of Project Effects						
					Lao PDR			Thailand			External Sponsors
					GOL/ Economy	Labor	Consumers	Consumers	EGAT	Sponsors	
BENEFITS	875.8		1,206.0	350.6							
Sales revenue Thai	847.3	1.36	1,150.5	303.2					303.2		
Forex premium					67.8				(67.8)		
Consumer surplus Thai	–		21.4	21.4					21.4		
Non incremental sales Lao	28.5	1.91	54.4	26.0			26.0				
Losses Lao	–		(20.4)	(20.4)			(20.4)				
COSTS	776.4		781.2	4.8							
Capital Investments	700.2		704.6	4.4							
Traded goods	345.0	1.08	372.6	27.6	(27.6)						
Non-traded goods	21.0	1.00	21.0	–	–						
Labor - foreign skilled	148.3	1.08	160.2	11.9	(11.9)						
Labor - local skilled	73.8	1.00	73.8	–							
Labor - local unskilled	35.0	0.71	24.9	(10.2)		10.2					
Fuel	48.2	1.08	52.1	3.9	(3.9)						
Taxes/other	28.8	–	–	(28.8)	28.8						

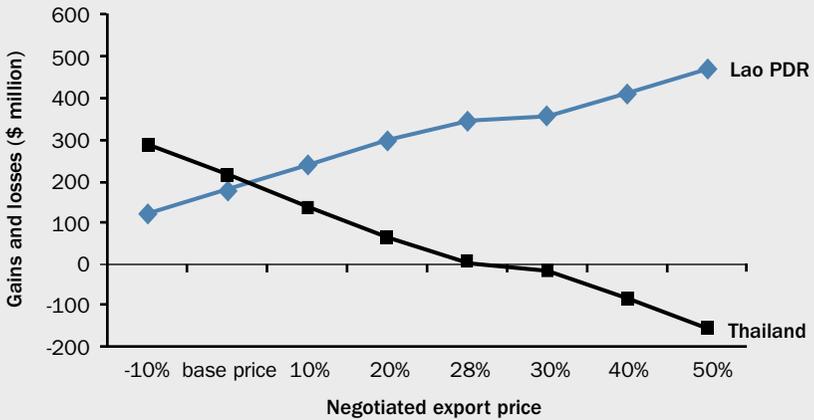
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Table 9.6 continued.

	Financial Present Values	Conversion Factors	Economic Present Values	Difference (EPV-FPV)	Distribution of Project Effects						
					Lao PDR			Thailand			External Sponsors
					GOL/ Economy	Labor	Consumers	Consumers	EGAT	Sponsors	
O&M	76.1		76.6	0.5							
Traded goods	37.6	1.08	40.6	3.0	(3.0)						
Non-traded goods	2.3	1.00	2.3	-	-						
Labor - foreign skilled	16.1	1.08	17.4	1.3	(1.3)						
Labor - local skilled	8.0	1.00	8.0	-	-						
Labor - local unskilled	3.8	0.71	2.7	(1.1)		1.1					
Fuel	5.2	1.08	5.7	0.4	0.4						
Taxes/other	3.1	-	-	(3.1)	(3.1)						
Transmission line in Thailand	79.6										
NET BENEFITS	179.0		389.4								
Dividends ^a	93.5		35.4		23.4						
Royalty payments	85.4	-	-	(85.4)	85.4				37.4	32.7	
Foreign exchange premium					0.4				(3.0)	2.6	
Gains and losses as per input in sales					160.9	11.3	5.6	21.4	155.8	34.4	35.4

^aDividends are allocated according to share of project sponsors.
EGAT = Electricity Generating Authority of Thailand, EPV = economic present value, FPV = financial present value, GOL = Government of Lao PDR, Lao PDR = Lao People's Democratic Republic, O&M = operating and maintenance.
Source: ADB (2005a).

Figure 9.1. Distribution of Gains and Losses



Lao PDR = Lao People's Democratic Republic.
 Source: ADB (2005a)

9.3.7 Sensitivity Analysis

Sensitivity analysis of the regional NPV and EIRR is undertaken with respect to key risk factors and assumptions expected to influence the viability of the project (Table 9.7). The project is not sensitive to changes within an expected range with switching values of around 55% for a capital cost increase and around 50% for a fall in sales to EGAT.

Table 9.7 Sensitivity Analysis: Regional

	Change	NPV (\$ million)	EIRR (%)	Switching Value
Base case		389.4	17.5	
Capital cost	20%	248.5	15.1	55%
Price elasticity (Thailand)	From 0.725 to 0.81	387.1	17.5	2.74
Price elasticity (Lao PDR)	From 0.43 to 0.81	399.0	17.6	0.02
Sales to EGAT	-20%	233.3	15.4	-50%
Capital+Sales	+20%/-20%	92.4	13.2	

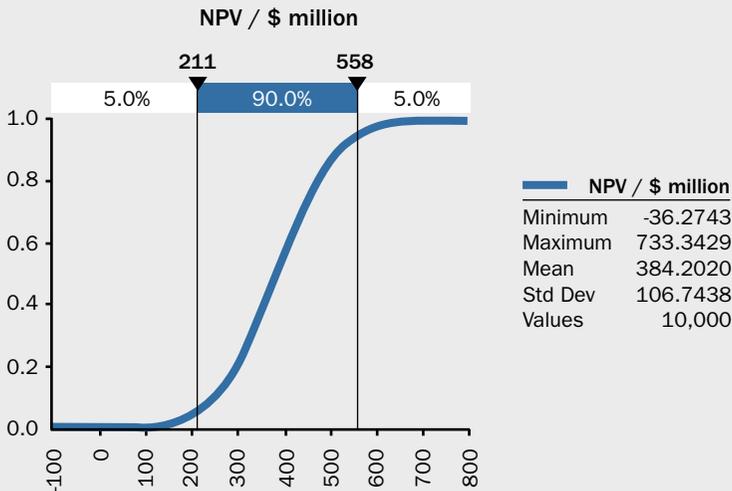
EGAT = Electricity Generating Authority of Thailand, EIRR = economic internal rate of return, Lao PDR = Lao People's Democratic Republic, NPV = net present value.
 Source: ADB (2005a).

9.3.8 Risk Analysis

Risk analysis was undertaken from the regional perspective using the @Risk software. Four variables were allowed to vary, including: capital cost, sales to EGAT during peak hours and price elasticities for both Thailand and Lao PDR. Normal distributions were assigned to the first two variables and triangular distributions to the price elasticities. Within a 90% confidence interval, the likely minimum and maximum values of these variables fall close to a 0.1 standard deviation from the mean.

Risk analysis was conducted based on 10,000 iterations, with the output variable being the probability-weighted NPV. Figure 9.2 indicates that the expected NPV is \$384.2 million, slightly below the calculated NPV in Table 9.7. There is a 90% chance that the NPV will fall to \$211 million or rise to \$558 million, indicating that the project is robust against simultaneous changes in key variables. The key result is the probability of project failure, defined by a negative NPV, which is well below 5%, indicating a very low risk.

Figure 9.2 Risk Results

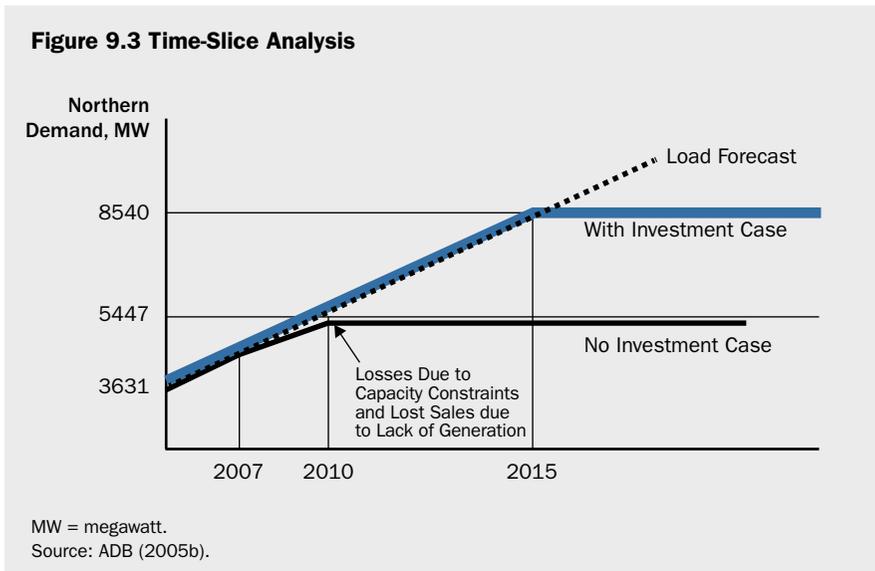


NPV = net present value, Std Dev = standard deviation.

Source: ADB (2005a).

9.4 Case Study: Power Transmission Expansion Project

Based on an actual project, the case study sets out a with- and without-project scenario and looks at Viet Nam’s power investment program over 2007–2015. The project involves individual subprojects, including a 500-kV transmission line and a series of substations for which financing is provided. The new transmission line will allow the transmission of power from the proposed large hydro projects in the south of the country to the load centers in northern Viet Nam, which are predicted to face power shortages without the project. As the transmission lines and substations are not stand-alone investments, a “time-slice” approach is used looking at the return to the overall investment in the northern region over the period 2007–2015 (see Figure 9.3).



The justification for the public sector investment in this project is linked to two factors: (i) the natural monopoly nature of power transmission; and (ii) the necessity to allow all competing power generators equal access to transmission and distribution facilities. The second reason is particularly relevant since the government plans to establish competition in power generation in Viet Nam, with a majority

of power producers at least partially privatized in the medium term. Under the long-term plan of the government, the transmission facilities of Electricity of Viet Nam (EVN) are to be consolidated in a separate unit and will be subject to formal regulation by the Electricity Regulatory Authority of Viet Nam.

9.4.1 Demand Analysis

During 1999–2004 in the years immediately prior to the planning of the expansion program, the average growth rate of electricity consumption in Viet Nam was 15.2%, with electricity sales increasing to 39.7 TWh in 2004 from 19.5 TWh in 1999. The demand growth was driven by rapid broad-based growth of the industrial and commercial sectors and an increase in electrification from less than 40% in 1990 to over 80% of households in 2004. Urbanization and increased living standards saw household demand growing at 19% per year over this period. Demand grew in all regions of the country at roughly similar rates.

The electricity demand elasticity to GDP growth during 1999–2004 was 1.9, and at the time the program was planned it was expected to remain at this high level in the medium term due to the highly energy-intensive nature of Viet Nam’s growth, where manufacturing industry has had a major role. Moreover, Viet Nam’s per capita consumption at around 500 kWh was relatively low compared to neighboring countries such as the People’s Republic of China and Thailand.

Table 9.8 presents the predicted national electricity demand, peak demand, load factors, and system losses at the time the program was planned. The forecasts indicate an annual growth in total demand of over 13% for 2004–2010 and 10% for 2010–2015.

Table 9.8 Electricity Demand Forecast for Viet Nam, 2004–2015

	Electricity demand (TWh/year)	Peak demand (MW)	Load factor (%)	System losses (%)
2004	39.7	8,400	65.7	14.7
2010	84.5	17,000	68.4	13.8
2015	139.2	26,000	69.1	12.3

MW = megawatt, TWh = terrawatt-hour.
Source: ADB (2005b).

The power system studies have shown that power demand in northern Viet Nam can be met using the existing power generation capacity in the north until 2007 and power transfers from southern and central Viet Nam.

The without-project investment program scenario assumes that there will be no investments in the power sector in northern Viet Nam beyond 2007. Under this scenario, the power system would be operated in a sub-optimal manner leading to the operation of existing inefficient and high-cost thermal power plants for base load power generation and high transmission losses due to increased power transfers to the northern region of the country.

The with-project case assumes the planned investments under the least-cost expansion plan will be made during the time slice of 2007–2015. Although there is likely to be surplus capacity at the end of the period to meet incremental demand, it is assumed conservatively that beyond 2015 any incremental sales would require further investments. Hence, benefits are treated as constant after 2015 up to 2025. No terminal value is assumed at 2025, the end of the life of the program.

Demand projections distinguish between types of consumers (residential and non-residential) and between incremental and non-incremental forms of electricity consumption. New consumers are those not yet connected to the grid before the project. Survey data suggest that without the project 19.081 million households will be connected to the grid, whilst the project study estimates that with the project, connections will be 19.202 million which implies an increase of just over 120,000 households with the project in 2008. Household connections over the life of the project can be expected to increase with general economic growth. The project study assumes that without the project the growth in household connections will be 2.6% annually whilst with the project, connections will be 3.2% (Table 9.9).

For non-residential consumers, the demand analysis uses growth rates of 9% for industry, 6% for commerce, and 4% for agriculture, based different income elasticities of demand.

Table 9.9 Residential Demand

Year	Number of Residential Customers	
	With-project	Without-project
2008	19,202,974	19,081,382
2009	19,809,985	19,563,751
2010	20,436,183	20,062,184
2011	21,082,176	20,577,206
2012	21,748,589	21,109,364
2013	22,436,068	21,659,222
2014	23,145,278	22,227,359
2015	23,876,906	22,814,378

Source: ADB (2005b).

9.4.2 Least-Cost Analysis

The plan for the power transmission system is determined by the location of the planned new power plants and high growth load centers. The overall power expansion plan for the country, as contained in Viet Nam's Master Plan 5 (updated in 2002), was developed using the WASP-III model. First, the least-cost planning model minimized the sum of discounted capital and operating costs by selecting an optimal generation plant mix for the expected demand growth and exogenous set of external prices. Here, only the essential information to understand the analysis are provided. The least-cost solution includes the 155-MW Song Bung 4 Hydropower Project, the 2,000-MW Mong Duong coal projects (2 times 1,000 MW) and the 1,100-MW O Mon 2 and 3 natural gas projects, which were all identified for potential financing over the period 2010–2015.

Once the optimal plant mix is selected, transmission planning requires minimizing the cost of connecting the selected power plants with the load centers, allowing for potential transmission losses and risks to power system security. Hence, least-cost planning is also required for the selection of transmission voltage and capacity as well as for the selection of location and capacity of substations to deliver power to load centers. Using cost minimization criteria, 500kV was selected as the transmission voltage.

As this project is planned as part of a sector program the costs of the full program for the with- and without-project scenarios is set out in Table 9.10. These are given initially in financial prices. The with-project and without-project cases are compared and are estimated to result in a net financial capital cost of VND116,234 billion over 2007–20154. The net O&M cost is estimated at 3% of the net capital cost. Also part of the net financial cost pertains to independent power production (IPP), as this is higher in the with-project case. The net financial costs exclude price contingencies.

Costs in VND (Billion)										
	2007	2008	2009	2010	2011	2012	2013	2014	2015	Total
With project										
Capital	16,002	35,789	47,066	64,045	41,489	11,912	4,570	961	0	221,834
O&M	0	1,074	1,412	1,921	1,245	357	137	29	0	6,175
IPP	0	408	629	1,000	871	2,241	2,543	2,622	1,507	11,821
										239,830
Without project										
Capital	11,000	20,405	20,000	30,000	20,005	2,100	1,900	190	0	
O&M	0	612	600	900	600	63	57	6	0	
IPP	0	300	310	352	794	1,000	1,000	1,316	201	
Net costs										
Capital	5,002	15,384	27,066	34,045	21,484	9,812	2,670	771	0	116,234
O&M	0	462	812	1,021	645	294	80	23	0	3,337
IPP	0	108	319	648	77	1,241	1,543	1,306	1,306	6,548
Share of O&M to capital		3%								126,119
IPP = independent power producer, O&M = operating and maintenance, VND = Vietnamese dong. Source: ADB (2005b).										

The power tariff of VND768/kWh is treated as constant in real terms over the life of the project and for simplicity is assumed to be the same for all users (residential and non-residential). At this tariff, project revenue is sufficient to generate a financial NPV at 12% of –VND 24.2 billion and a financial internal rate of return (FIRR) of 6.4%. Although it is low, this return is still above the real cost of capital to EVN, so that

the project is financially viable at the expected real tariff. However the gains to the economy from the project are considerably greater than the financial return.

9.4.3 Project Benefits

The economic analysis is carried out using the domestic price numeraire and the Vietnamese Dong (VND) as the unit of currency. The economic benefits are derived by comparing the performance of the power sector in Viet Nam under the with- and without-investment scenarios during 2007–2025, in terms of:

- (i) higher sales to both existing and new residential customers;
- (ii) resource cost savings in terms of displaced self-generation among industrial, commercial and agricultural customers;
- (iii) lower per unit fuel cost as the generation and transmission system will be operated based on least-cost operations planning.

The total generation is maintained more or less at the same level as the with-project case until 2010 using surplus thermal generation capacity available in the south of Viet Nam. After 2010, the total generation under the without-project case falls below the total generation under the with-project case as the transmission constraint becomes binding and overall power usage is lower in the without-project scenario. The share of thermal power and the fuel cost per unit of thermal energy generated is also higher in the without-project case as compared to the with-project case due to non-optimum dispatch of power in the without-project case.

Comparing with- and without-project scenarios, the economic benefits of the power sector development program can be divided into several benefit streams:

- (i) Economic benefits due to electricity consumption by new residential customers, divided into non-incremental benefits (that is, replacement of substitutes such as kerosene used for lighting) valued at resource cost savings, and incremental benefits due to increased electricity consumption valued at WTP.
- (ii) Economic benefits due to incremental consumption of existing residential customers, valued at WTP. In the without-project

case, such benefits would be foregone due to the curtailment of electricity supply due to shortages.

- (iii) Resource cost savings to industrial, commercial, and agricultural customers due to their increased electricity consumption in the with-project case. In the without-project case, it is assumed that such consumers would resort to higher cost diesel-based self-generation to meet the shortfall in electricity supply.

The resource cost savings to the national economy due to the replacement of more expensive thermal power plants with more efficient forms of thermal and hydropower generation in the with-project case are not treated as separate benefits. This is because the project is by definition the least-cost expansion alternative and the system-wide cost savings due to lower fuel cost in the least-cost expansion plan are already accounted for in estimating the incremental project cost. Hence, these savings are not included separately but are implicit in the with- and without-project cost comparison.

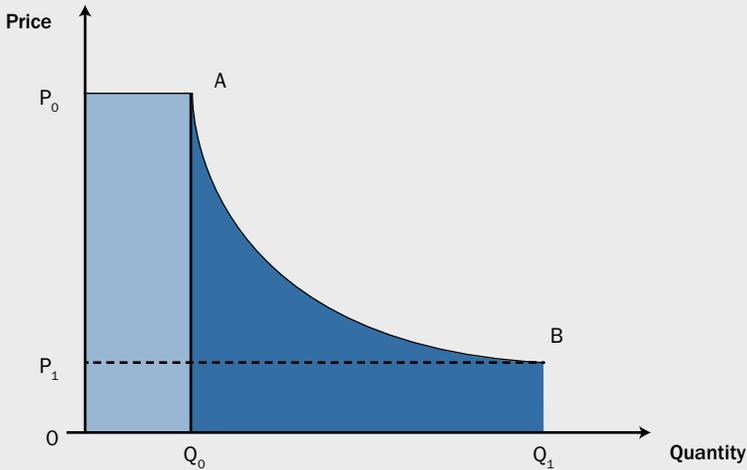
A: Benefits to New Residential Consumers

The economic benefits for new residential customers, consisting of non-incremental and incremental consumption, are estimated using the approach described in Chapter 8 (see Choynowski 2002). For residential customers previously with no connection to the grid, the expansion will allow the replacement of other light and heating sources (such as kerosene and fuel-wood) by electricity, which is both cheaper and more convenient. Surveys of households without electricity connection imply an average cost from other sources of VND5,127/kWh-equivalent and an average usage of 119 kWh-equivalent. These values correspond to P_0 and Q_0 , respectively, in Figure 9.4.

The resource cost savings pertaining to non-incremental consumption amount to VND610,113 (= 5,127 x 119) per consumer per year, represented as area $0P_0AQ_0$ in Figure 9.4. The total non-incremental benefits are derived by multiplying the forecast increase in consumers by VND610,113 for each year (Table 9.11).

For illustration purposes, the non-incremental benefit of VND74,185 million for year 2008 is calculated as follows:

$$\begin{aligned} \text{Non-incremental Benefit} &= \text{Resource Cost Savings} \times \text{New Customers} \\ &= (P_0 \times Q_0) \times (\text{with-project} - \text{without-project customers}) \\ &= (5,127 \times 119) \times (121,592) = \text{VND74,185 million.} \end{aligned}$$

Figure 9.4 Demand Curve for New Residential Customers

P_0 : Price of alternative source of energy
 P_1 : Electricity tariff
 Q_0 : Energy consumption per household in the absence of electricity
 Q_1 : Electricity consumption per household at the prevailing tariff.

Table 9.11 New Residential Customers: Non-incremental Benefits

	Q_0 (kWh)	P_0 (VND)	New customers	Non-incremental consumption (GWh)	Non-incremental benefits (Mn,VND)
2008	119	5,127	121,592	14	74,185
2009	119	5,127	246,234	29	150,231
2010	119	5,127	73,999	45	228,182
2011	119	5,127	504,970	60	308,089
2012	119	5,127	639,225	76	389,999
2013	119	5,127	776,846	92	473,964
2014	119	5,127	917,919	109	560,034
2015	119	5,127	1,062,528	126	648,262

GWh = gigawatt-hour, kWh = kilowatt-hour, Mn = million, VND = Vietnamese dong.
 Source: ADB (2005b).

On the other hand, incremental benefits refer to the additional electricity usage of new customers. The magnitude of these will vary

with the electricity tariff. They are represented graphically by the area ABQ_1Q_0 in Figure 9.4, where P_1 is the tariff charged to new customers and Q_1 is their demand at this charge. Where non-linear demand-price relations are involved (as shown in Figure 9.4), incremental benefits are valued based on the procedure suggested in Choynowski (2002). The formulation expresses WTP for incremental power (B) as:

$$B = Q_1(P_1 - 1/\beta) - Q_0(P_0 - 1/\beta) \quad (1)$$

where Q_0 and P_0 are the without-expansion consumption and price points, and Q_1 and P_1 are the corresponding with-expansion points. β is the coefficient from a semi-log demand relation $\ln.Q = \alpha + \beta P$. The solution of equation (1) requires a value for β . When econometric estimation of β is not available, it can be inferred from the planned price P_1 and an approximate estimate of with-expansion demand Q_1 . In this analysis the without-expansion points are $P_0 = 5,127$ and $Q_0 = 119$ reflecting the usage without the project. Approximate estimates imply a planned tariff in 2008 of VND768 (P_1), and usage per new customer of 1,351 kWh (Q_1). The average usage for new customers was obtained through a survey of recently electrified similar villages. With these four points, a value of β can be inferred, as $\beta = (\ln Q_1 - \ln Q_0)/(P_1 - P_0)$.⁹ Therefore,

$$\begin{aligned} \beta &= (\ln 1,351 - \ln 119)/(768 - 5,127) \\ &= -0.00056 \end{aligned}$$

In calculating incremental benefits over 2008–2025, real residential tariffs are assumed to remain the same (so, P_1 is constant). The benefit per consumer, using equation (1), is calculated as follows (see Table 9.12):

$$\begin{aligned} B &= 1,351 * (768 - 1/-0.00056) - 119 * (5,127 - 1/-0.00056) \\ B &= \text{VND}2,637,926 \end{aligned}$$

Multiplying this benefit with the number of additional customers for 2008 of 121,592 gives a total incremental benefit of VND320,751 million; similar calculations are done for subsequent years. This approach assumes that the new customers consume the same quantity throughout the project period. This is not realistic as consumption may increase with an increase in income. However, since the demand function using the two data points does not include income as a variable, it is not

⁹ This follows since: $\ln Q_0 = \alpha + \beta.P_0$ and $\ln Q_1 = \alpha + \beta.P_1$. Rearranging, $\alpha = \ln Q_0 - \beta.P_0 = \ln Q_1 - \beta.P_1$ and $\beta (P_1 - P_0) = (\ln Q_1 - \ln Q_0)$. So, $\beta = (\ln Q_1 - \ln Q_0)/(P_1 - P_0)$.

possible to account for the increased consumption. This simplification underestimates the benefits but if, as here, the EIRR is greater than the cut-off point without adjustment for an income effect, the simplification does not alter the decision on acceptance of the project based on economic viability.

Table 9.12 New Residential Customers: Incremental Benefits

	P_0 (VND/kWh)	Q_0 (kWh)	P_1 (VND/kWh)	Q_1 (kWh)	New customers	Incremental consumption (GWh)	Benefits/ Consumer (VND)	Incremental benefits (VND million)
2008	5,127	119	768	1,351	121,592	150	2,637,926	320,751
2009	5,127	119	768	1,351	246,234	303	2,637,926	649,547
2010	5,127	119	768	1,351	373,999	461	2,637,926	986,582
2011	5,127	119	768	1,351	504,970	622	2,637,926	1,332,073
2012	5,127	119	768	1,351	639,225	788	2,637,926	1,686,228
2013	5,127	119	768	1,351	776,846	957	2,637,926	2,049,262
2014	5,127	119	768	1,351	917,919	1,131	2,637,926	2,421,402
2015	5,127	119	768	1,351	1,062,528	1,309	2,637,926	2,802,870

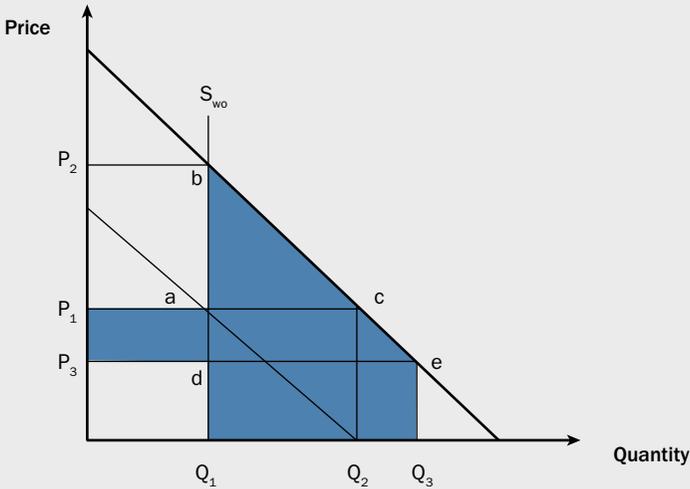
GWh = gigawatt-hour, kWh = kilowatt-hour, P_0 = price point without the project, P_1 = price point with the project, Q_0 = consumption point without the project, Q_1 = consumption point with the project, VND = Vietnamese dong.

Source: ADB (2005b).

B. Benefits to Existing Residential Consumers

Without the project, existing residential customers consume 1,351 kWh (= Q_1) and pay the without-project tariff of VND804/kWh (= P_1). With the project, they will pay the with-project tariff of VND768/kWh (= P_3) and their consumption is projected to increase by 6.5% per year over the project life. This is an approximate estimate based on past trends in consumption that reflect rising household income over the project's lifetime. Thus by 2009, consumption of these existing consumers will be 1,439 kWh (= Q_3). The new higher demand line reflects greater demand at every tariff level due to this income effect. Graphically, the WTP for existing residential customers is reflected in the area Q_1bQ_3 in Figure 9.5,¹⁰ where P_3 and Q_3 are the tariff and usage with the expansion while P_1 and Q_2 are the tariff and usage without the expansion.

¹⁰ Taken from Figure 8.3 in Chapter 8.

Figure 9.5 Shift in Demand

The incremental benefit from existing residential customers comprises of the incremental revenue (area Q_1deQ_3) and consumer surplus (area dbc). Incremental revenue is the product of the with-project tariff and incremental consumption. For example, the incremental consumption revenue in 2009 is derived by multiplying the difference in the with- and without-project consumption (1,439 – 1,351) with the number of without-project customers of 19,563,751 to get 1,718 GWh. This result is then multiplied by the with-project tariff of VND768/kWh to get VND1,319,417 million (see Table 9.13).

As discussed in Chapter 8, where there is an outward shift in the demand curve due to an income effect, calculation of consumer surplus requires an estimate of the market-clearing price in the without-project case at the new level of demand (that is, P_2 rather than the observed price of P_1). Since P_2 is unknown, consumer surplus (CS) can be approximated using equation (5) from Chapter 8. Thus in this case total consumer surplus for all existing residential users is calculated using the equation

$$CS = 0.5[P_E (\Delta Q)^2 / (e_d Q_1)] \quad (2)$$

where P_E is the without-project tariff of VND804/kWh, ΔQ is incremental consumption, e_d is equal to -0.43 which is an average price elasticity of

Table 9.13 Existing Residential Customers: Incremental Benefits

	Without-project customers	P ₁ (kWh)	Q ₁ (kWh)	P ₂ (VND/ kWh)	Q ₂ (kWh)	per Household (kWh)	Total (GWh)	Incremental benefits (VND million)		
								Revenue	Consumer Surplus	Total
2008	19,081,382	804	1,351	768	1,351	0	0	0	0	0
2009	19,563,751	804	1,351	768	1,439	88	1,718	1,319,417	98,026	1,417,443
2010	20,062,184	804	1,351	768	1,532	181	3,638	2,794,012	402,493	3,196,505
2011	20,577,206	804	1,351	768	1,632	281	5,781	4,439,777	930,394	5,370,170
2012	21,109,364	804	1,351	768	1,738	387	8,170	6,274,301	1,700,736	7,975,037
2013	21,659,222	804	1,351	768	1,851	500	10,829	8,316,926	2,734,731	11,051,657
2014	22,227,359	804	1,351	768	1,971	620	13,788	10,588,922	4,055,998	14,644,920
2015	22,814,378	804	1,351	768	2,099	748	17,075	13,113,675	5,690,793	18,804,468

GWh = gigawatt-hour, kWh = kilowatt-hour, P₁ = without project tariff, P₂ = with project tariff, Q₁ = without project consumption, Q₂ = with project consumption, VND = Vietnamese dong.
Source: ADB (2005b).

demand for power,¹¹ and Q_1 is the without-project consumption. To illustrate for year 2009:

$$\begin{aligned} \text{Consumer surplus} &= \frac{0.5 \times (804 \times 1,718^2)}{0.43 \times (1,351 \times 19,563,751)} \\ &= \text{VND}98,026 \text{ million} \end{aligned}$$

Similar calculations are done for subsequent years.

C: Benefits to Non-Residential Consumers

Existing non-residential consumers consist of producers in the industry, commerce, and agriculture sectors. A survey conducted by EVN shows that on average an industrial customer uses 9,000 kWh per year but only 4,000 kWh of electricity is obtained from the grid. Thus, 5,000 kWh is generated by small diesel generators to meet the total demand. Similarly, about 1,200 kWh and 120 kWh of self-generated electricity are used by commercial and agricultural customers, respectively. Thus, the average producer finds only part of their electricity needs supplied by the grid.

Without the project, given the high expected rate of economic growth and the binding constraint on additional generating capacity, it is assumed that the increased power needs of existing non-residential users would have to be self-generated. The cost of self-generated electricity is estimated¹² at VND2,400/kWh. Based on previous trends, it is assumed that, without the project, self-generation needs of existing businesses will increase at 9% for industry, 6% for commerce, and 4% for agriculture.

Without the project in 2008, it is estimated that there would be 894 GWh of high-cost self-generated electricity from industrial users, 151 GWh from commercial users, and 21 GWh from agricultural users. The benefit to the economy is therefore the resource cost saving of VND2,400/kWh multiplied by the self-generated electricity that will be substituted by the project.

Table 9.14 shows the total self-generation by industry, commerce, and agriculture and the estimated non-incremental benefits (valued at resource cost savings) under the project. For illustration in 2008, benefits in industry are:

$$\text{VND}2,400/\text{kWh} \times 894 \text{ GWh} = \text{VND}2,145,600 \text{ million}$$

¹¹ This elasticity is based on the average for Asian developing countries (see Appendix 8.1 in Chapter 8). Note that this equals the implied elasticity in the application of equation (1) above, since in the semi-log form of demand equation price elasticity equals $\beta.P_i$. Here $\beta.P_i = -0.00056 \times 768 = -0.43$.

¹² EVN Tariffs: Interim Report, Economic Consulting Associates, Robert Vernstorm Associates, September 2003.

Table 9.14 Existing Non-Residential Customers: Non-incremental Benefits

	Self-generation without the project, (GWh)				Non-incremental benefits (VND million)			
	Industry	Commerce	Agriculture	Total	Industry	Commerce	Agriculture	Total
2008	894	151	21	1,066	2,145,600	362,400	50,400	2,558,400
2009	974	160	22	1,156	2,338,704	384,144	52,416	2,775,264
2010	1,062	170	23	1,255	2,549,187	407,193	54,513	3,010,893
2011	1,158	180	24	1,361	2,778,614	431,624	56,693	3,266,932
2012	1,262	191	25	1,477	3,028,690	457,522	58,961	3,545,172
2013	1,376	202	26	1,603	3,301,272	484,973	61,319	3,847,564
2014	1,499	214	27	1,740	3,598,386	514,071	63,772	4,176,229
2015	1,634	227	28	1,889	3,922,241	544,916	66,323	4,533,479
Growth	9%	6%	4%					

GWh = gigawatt-hour, VND = Vietnamese dong.
Source: ADB (2005b).

The availability of cheap electricity may induce the establishment of new businesses. However, predicting the number of new businesses due to the availability of cheap grid electricity is not easy. Survey data of non-residential customers did not provide useful information on business expansion prospects. Further the high projected growth of existing non-residential users is likely to capture spin-offs and expansion of existing enterprises. Hence this additional form of benefit is not reflected in the analysis. However, for purposes of illustration, Appendix 9.1 explains how this type of benefit could be valued.

D: Consumer and Producer Surplus

The benefits just described are all gross benefits in that they do not capture how the welfare of electricity users is affected. This requires a comparison between benefits received—as measured by either WTP or cost savings—and what users actually pay, as reflected in the tariff they are charged. The difference between economic benefits and financial revenue from the tariff reflects consumer surplus for residential consumers and producer surplus for non-residential consumers. Revenues paid are included in the financial analysis of the project and in economic benefits

(before any economic pricing adjustments). Table 9.15 summarizes consumer and producer surplus by giving the discounted present values (at 12%) of the benefit and revenue flows over the project's lifetime.

Table 9.15 Consumer and Producer Surplus (present values), VND billion

	Revenues	Benefits	Net benefits	
Residential				
Existing	47,900	66,138	18,238	Consumer surplus
New				
Non-incremental	401	2,679	2,277	Consumer surplus
Incremental	4,539	11,582	7,042	Consumer surplus
Non-residential				
Existing				
Non-incremental	7,641	23,877	16,237	Producer surplus

VND = Vietnamese dong.
Source: ADB (2005b).

9.4.4 Economic Price Adjustments

The above benefit calculations are in financial prices. As a further relatively minor adjustment the costs and benefit estimates need to be converted to economic prices. To do this, the benefit and cost streams at financial prices need to be decomposed first into primary factors. The relevant coefficients applied are given in Table 9.16. Since non-incremental benefits are cost savings, they have a different set of coefficients from those applicable to incremental benefits. As energy is internationally traded, the traded component of non-incremental benefits and energy purchase (under IPP) is high. Incremental benefits, on the other hand, reflect WTP which is treated as non-traded. Transfers here are all taxes.

The coefficients are applied to disaggregate the project benefit and cost flows into the five primary factors, which are then revalued by a set of conversion factors (CFs). For Viet Nam, the original project applies a SERF of 1.1, so all traded costs and benefits are raised in value by 10% to convert them to domestic prices. The skilled labor market is treated as sufficiently competitive for wages to reflect marginal productivity (so, the CF is 1.0). The unskilled labor market, however, is treated as in disequilibrium

with a labor surplus and a SWRF of 0.5 is used. Transfers have a CF of zero (Table 9.17).

Table 9.16 Primary Factor Coefficients

	Costs			Benefits		
	Capital	O&M	IPP	Non-incremental		Incremental
				Residential	Non-residential	
Traded	0.55	0.30	0.95	0.70	0.85	0
Nontraded	0.20	0.10	0.05	0.20	0.05	1
Labor-Skilled	0.05	0.45	0	0	0.10	0
Labor-Unskilled	0.15	0.05	0	0	0	0
Transfers	0.05	0.10	0	0.10	0	0
Total	1	1	1	1	1	1

IPP = independent power production, O&M = operating and maintenance.
Source: ADB (2005b).

Table 9.17 Primary Inputs and Conversion Factors

Primary inputs	Conversion factors
Traded goods	SERF = 1.1
Non-traded goods	1.0
Labor – Skilled	1.0
Labor – Unskilled	SWRF = 0.5
Transfers	0

SERF = shadow exchange rate factor, SWRF = shadow wage rate factor.
Source: ADB (2005b).

9.4.5 Cost-Benefit Analysis (CBA)

The results of the cost-benefit analysis once economic pricing is introduced are summarized in Table 9.18. It should be noted that the fuel cost and the power purchase cost from IPP is higher in the with-project case compared to the without-project case due to the higher electricity sales in the with-project case. The analysis shows that economic benefits exceed costs when discounted at 12% and the investment program has a positive net present value of VND26,952 billion and an EIRR of 17.9%.

Table 9.18 Economic Cash Flow: Domestic Price Numeraire, VND billion

	BENEFITS						Total	Net
	Residential		Non residential					
	Costs	New Non-incremental	New Incremental	Existing Incremental	Existing Non-incremental			
2007	4,652						(4,652)	
2008	14,843	72	321	0	2,776	3,169	(11,674)	
2009	26,256	146	650	1,417	3,011	5,224	(21,032)	
2010	33,296	221	987	3,197	3,267	7,671	(25,624)	
2011	20,648	299	1,332	5,370	3,545	10,546	(10,102)	
2012	10,750	378	1,686	7,975	3,847	13,886	3,136	
2013	4,245	460	2,049	11,052	4,175	17,735	13,490	
2014	2,168	543	2,421	14,645	4,531	22,141	19,973	
2015	1,451	629	2,803	18,804	4,919	27,155	25,704	
2016	1,451	629	2,803	18,804	4,919	27,155	25,704	
2017	1,451	629	2,803	18,804	4,919	27,155	25,704	
2018	1,451	629	2,803	18,804	4,919	27,155	25,704	
2019	1,451	629	2,803	18,804	4,919	27,155	25,704	
2020	1,451	629	2,803	18,804	4,919	27,155	25,704	
2021	1,451	629	2,803	18,804	4,919	27,155	25,704	
2022	1,451	629	2,803	18,804	4,919	27,155	25,704	
2023	1,451	629	2,803	18,804	4,919	27,155	25,704	
2024	1,451	629	2,803	18,804	4,919	27,155	25,704	
2025	1,451	629	2,803	18,804	4,919	27,155	25,704	
NPV							26,952	
EIRR							17.9%	

EIRR = economic internal rate of return, NPV = net present value, VND = Vietnamese dong.
Source: ADB (2005b).

9.4.6 Distribution Analysis

The distribution analysis is carried out to determine how the project benefits and costs are distributed among different stakeholders (Table 9.19). Financial cash flows and economic benefits and revenues are discounted at 12%. At this discount rate, the financial NPV to the utility EVN is negative as the internal rate of return is below 12%. The distribution analysis shows that, unsurprisingly, the bulk of gains go to electricity users in the form of consumer and producers surplus as

Table 9.19 Distribution Analysis

Consumer/Producer Surplus							
	Revenues (financial price)	Benefits (financial price)	Net benefits				
EVN's FNPV			-24,182				
Add:							
Residential							
Existing	47,900	66,138	18,238	Consumer surplus			
New							
Non-incremental	401	2,679	2,277	Consumer surplus			
Incremental	4,539	11,582	7,428	Consumer surplus			
Non-residential							
Existing							
Non-incremental	7,641	23,877	16,237	Producer surplus			
Net benefits in financial prices			19,998				
Add:							
Government	Forex premium		-2,593				
	Transfers		3,769				
Labor	Unskilled shadow wage		5,779				
Net benefits in economic prices			26,952				
Income Change (EPV-FPV)			6,954				
Distribution of Gains from Economic Pricing							
	Financial PV @ domestic prices	Economic PV @ domestic prices	Income change EPV- FPV	EPV - FPV = Gains to:			
				Government	Labor (unskilled)	Labor (skilled)	Total gains
Traded	-25,931	-28,524	-2,593	-2,593			-2,593
Non- traded	63,678	63,678	0				0
Labor- Skilled	-2,423	-2,423	0				0
Labor- Unskilled	-11,557	-5,779	5,779		5,779		5,779
Transfers	-3,769	0	3,769	3,769			3,769
Net	19,998	26,952	6,954	1,176			6,954

EPV = economic present value, EVN = Electricity of Viet Nam, FNPV = financial net present value, FPV = financial present value, PV = present value.
Source: ADB (2005b).

shown in Table 9.19. Unskilled workers employed in construction and operations also gain as their alternative job opportunities are taken to be limited. Thus they gain the difference between the market and the economic wage. The government has a net gain, due to its collection of taxes paid by the project. The project is a net user of foreign exchange and so the government loses the foreign exchange premium of 10%.

As a final stage in the distribution analysis, a rough estimate is made of its direct poverty impact. This requires an approximate estimate of the proportion of the income changes for the different stakeholder groups that accrue to those below the poverty line. A brief survey of users indicates that approximately 20% of new residential consumers and 10% of non-residential users are likely to be below the poverty line. On the other hand, the bulk of unskilled workers employed in project construction and operations and maintenance are likely to be poor and an estimate of 80% is used. Finally, any indirect impact on the poor through higher government income is picked up by assuming 10% of additional government income created by the project ultimately benefits the poor. These assumptions give a poverty impact ratio (that is, the share of the poor in net benefits) of 30.5% (see Table 9.20).

	Stakeholder Income Change		
	Present values (VND billion)	Share of poor	Income change for poor
Financial NPV	-24,182	0	0
Residential			
Consumer surplus			
Existing	18,238	0	0
New, non-incremental	2,277	0.2	455
New, incremental	7,428	0.2	1,485
Non-residential			
Producer surplus	16,237	0.1	1,624
Government	1,176	0.1	118
Unskilled labor	5,779	0.8	4,623
Economic NPV	26,952		8,305
Poverty impact ratio	0.3081		

NPV = net present values, VND = Vietnamese dong.
Source: ADB (2005b).

9.4.7 Sensitivity Analysis

The sensitivity of the EIRR to several adverse movements in key variables is shown in Table 9.21. The sensitivity analysis shows that the EIRR of the investment program is sufficiently robust to withstand adverse movements in key variables. All of the switching values for individual variables are high; for example, it will take a 40% capital cost increase in real terms for the project to be marginal.

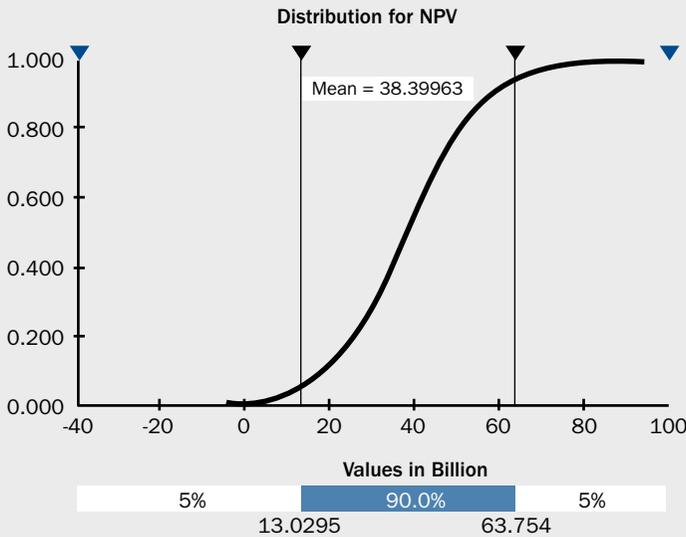
Table 9.21 Sensitivity Analysis

	Change (%)	NPV (VND billion)	EIRR (%)	Switching value (%)
Base Case		26,952	17.9	
Capital Cost	20	13,589	14.6	40
O&M	20	26,552	17.8	1,347
IPP cost	20	25,692	17.7	428
Capital+O&M+IPP	20	11,928	14.3	
Diesel self-gen cost	20% lower	21,771	16.8	-104
With-project tariff	20% lower	16,461	15.7	-51
New non-residential	include	33,229	19.4	

EIRR = economic internal rate of return, IPP = independent power production, NPV = net present value, O&M = operating and maintenance, VND = Vietnamese dong.
Source: ADB (2005b).

9.4.8 Risk Analysis

Although the results of the cost-benefit analysis (CBA) are robust to adverse changes in key variables, a risk analysis is carried out using the @ RISK software by probabilistically simulating simultaneous changes in key variables. It is assumed that all key variables are normally distributed, with capital costs ranging from 1.3 and 0.7 of base costs, and O&M and IPP prices ranging from 1.15 and 0.85 of base costs. The diesel self-generating cost and with-project tariff are also tested with a plus or minus 20% change in cost. The analysis shows the probability-weighted NPV at VND38.4 billion. The probability that the NPV will be negative is less than 5%, which suggests a low-risk project.

Figure 9.6 Risk Analysis

NPV = net present value.
Source: ADB (2005b).

9.5 Conclusions

This chapter has illustrated the application of economic analysis techniques to the appraisal of two different types of power project—a power generation project for export which has regional characteristics and a transmission line project that is part of a wider expansion program. The key focus of the power generation project is on the regional aspect and on estimating the distributional effect between the two participating economies in the region and foreign investors. The emphasis in the second case study is on ways of quantifying power benefits particularly from incremental consumption using elasticity-based estimates of WTP.

Appendix 9.1 Incremental Benefits to New Non-Residential Customers

It is assumed that 10% of the total of existing industrial and commercial customers will establish new businesses as a result of the project. The benefits from new non-residential customers can be estimated using the approach in Choynowski (2002) with a slight modification. In the case of new customers, the gross benefit is equal to the total area under the demand curve since their starting consumption is zero. Therefore, the demand function should be integrated between zero and Q_3 (see Figure 8.3 in Chapter 8). In the case where a customer uses an alternative source such as kerosene, the consumer surplus portion under the without-project situation is the same as in the with-project situation. Therefore, this is not included in the benefits. However, in this case where the new customer does not consume alternative energy sources, the total area of the demand curve bounded by zero and Q_3 constitute the benefits.

For illustration purposes, only the industry and commerce sectors are considered in the analysis. Based on survey information, P_0 and Q_0 for industry are considered to be VND2,400/kWh and 5,000 kWh, respectively. P_3 and Q_3 for the same are VND768/kWh and 9,000 kWh, respectively. These points on the demand curve are used to establish the demand function¹³ for the industry sector:

$$\ln Q = 9.38 - 0.0003602 * P$$

In order to use this equation for estimating incremental benefits, the price at zero quantity is required. However, since the price at zero quantity is not defined in the semi-log demand function, a price corresponding to a quantity close to zero (0.1) was estimated at VND32,441.3.¹⁴ This price and quantity of 0.1 was used to obtain the benefit per new industrial customer at VND 31,897,136. The same approach is followed in estimating the benefits for commercial customers. The benefits per customer are then multiplied by the estimated number of new non-residential customers to get the incremental benefits. Table A9.1.1 shows the results. Inclusion of this additional benefit in the sensitivity analysis raises the EIRR to over 19%.

¹³ See Chapter 8 for the procedure.

¹⁴ This price is estimated as $(\ln[0.1] - a)/b$, where 0.1 is the quantity close to 0, a is the intercept, and b is the slope.

Table A9.1.1.1 New Non-residential Customers: Incremental Benefits

	New customers (million)			Incremental consumption (GWh)			Benefits/Customer (VND)			Incremental benefits (VND million)		
	Industry	Commerce	Total	Industry	Commerce	Total	Industry	Commerce	Total	Industry	Commerce	Total
2008	0.018	0.01	185.86	160.92	24.94	31,897,136	7,964,792	570,321	100,224	670,544		
2009	0.019	0.01	201.84	175.40	26.44	31,897,136	7,964,792	621,650	106,237	727,887		
2010	0.021	0.01	219.21	191.19	28.02	31,897,136	7,964,792	677,598	112,611	790,209		
2011	0.023	0.01	238.10	208.40	29.70	31,897,136	7,964,792	738,582	119,368	857,950		
2012	0.025	0.02	258.64	227.15	31.49	31,897,136	7,964,792	805,054	126,530	931,584		
2013	0.028	0.02	280.97	247.60	33.38	31,897,136	7,964,792	877,509	134,122	1,011,631		
2014	0.030	0.02	305.26	269.88	35.38	31,897,136	7,964,792	956,485	142,169	1,098,654		
2015	0.033	0.02	331.67	294.17	37.50	31,897,136	7,964,792	1,042,569	150,699	1,193,268		

GWh = gigawatt-hour, VND = Vietnamese dong.
Source: ADB (2005b).

Bibliography and References

- Abdel-Khalek, G. 1988. "Income and Price Elasticities of Energy Consumption in Egypt." *Energy Economics* 10(1):47–58.
- Adamowicz, W. 2004. "What's it Worth?: An Examination of Historical Trends and Future Directions in Environmental Valuation." *Australian Journal of Agricultural and Resource Economics* 48(3):419–43.
- Adamowicz, W. L., P. C. Boxall, J. J. Louviere, J. Swait, and M. Williams. 1999. "Stated Preference Methods for Valuing Environmental Amenities." In I. Bateman and K. Willis, eds., *Valuing Environmental Preferences: Theory and Practice of the Contingent Valuation Method in the U.S., E.C. and Developing Countries*. New York: Oxford University Press.
- Adhikari, R., and J. Weiss. 1999. *Economic Analysis of Sub-Regional Projects*, Asian Development Bank Methodology Series No. 1. ADB, Manila.
- _____. 2004. "Methodological Framework for the Economic Analysis of Regional Projects." In A. Estevadeordal, B. Frantz, and R. N. Tam, eds. *Regional Public Goods from Theory to Practice*. Inter-American Development Bank and ADB, Washington, DC.
- Ahmad, E. and N. Stern. 1987. "Alternative Sources of Government Revenue: Illustrations from India 1979-80." In D. Newbury and N. Stern, eds. *The Theory of Taxation for Developing Countries*. Oxford University Press for the World Bank, Oxford and New York.
- Ali, I. 1989. *A Framework for Evaluating the Economic Benefits of Power Projects*. Asian Development Bank Economic Staff Paper No. 43. ADB, Manila.

- Ali, I. 1991. *Economic Analysis of Investment in Power Systems*. Asian Development Bank Economic Staff Paper No. 49. ADB, Manila.
- Altaf, M. A., D. D. Whittington, H. Jamal, and V. K. Smith. 1993. "Rethinking Rural Water Supply Policy in the Punjab, Pakistan." *Water Resources Research* 29(7):1943–54.
- Amarawickrama, H. A., and L. C. Hunt. 2007. *Electricity Demand for Sri Lanka: A Time Series Analysis*. Surrey Energy Economics Centre (SEEC), Department of Economics, University of Surrey.
- Amarullah, M. 1983. *Pricing of Electricity in Indonesia*. Thesis/Dissertation, University of Houston. Texas, United States.
- Amiel, Y., J. Creedy, and S. Hurn. 1999. "Measuring Attitudes Towards Inequality." *Scandinavian Journal of Economics* 101:83–96.
- An, L., F. Lupi, J. Liu, M. A. Linderman, and J. Huang. 2002. "Modeling the Choice to Switch from Fuelwood to Electricity: Implications for Giant Panda Habitat Conservation." *Ecological Economics* 42(3):445–57.
- Ang, B. W. 1988. "Electricity-Output Ratio and Sectoral Electricity Use: The Case of East and Southeast Asian Developing Countries." *Energy Policy* 16(2):115–21.
- Ang, B. W., T. N. Goh, and X. Q. Liu. 1992. "Residential Electricity Demand in Singapore." *Energy* 17(11):37–46.
- Archondo-Callao, R. 2004. *Road Economic Decision Model: Software User Guide and Case-Studies, Sub-Saharan Africa Transport Policy Program*. Working Paper Number 78, Africa Region, World Bank, Washington DC.
- Arshad, M. K., and U. Ahmed. 2009. *Energy Demand in Pakistan: A Disaggregate Analysis*. MPRA Paper No. 15056, posted 06 May 2009.
- Arrow, K. 1995. *Intergenerational Equity and the Rate of Discount in Long-Term Social Investment*. Paper presented at the IEA World Congress, December, Tunis, Tunisia.
- Arrow, K. and R. Lind. 1970. "Uncertainty and the Evaluation of Public Investment Decisions." *American Economic Review* 86:364–78.
- Arrow, K. and A. Fisher. 1974. "Environmental Preservation, Uncertainty and Irreversibility." *Quarterly Journal of Economics* 88:312–19.

- Arrow, K., R. Solow, P. R. Portney, E. E. Leamer, R. Radner, and H. Schuman. 1993. "Report of the NOAA Panel on Contingent Valuation." *Federal Register* 58(10):4601–14.
- Asian Development Bank (ADB). 1996. *Economic Evaluation of Environmental Impacts*. ADB, Manila.
- _____. 1997. *Guidelines for the Economic Analysis of Projects*. ADB, Manila.
- _____. 1999. *Handbook for the Economic Analysis of Water Supply Projects*. ADB, Manila.
- _____. 2000. *Handbook for the Economic Analysis of Health Sector Projects*. ADB, Manila.
- _____. 2001. *Handbook for Integrating Poverty Impact Assessment in the Economic Analysis of Projects*. ADB, Manila.
- _____. 2002. *Handbook for Integrating Risk Analysis in the Economic Analysis of Projects*. ADB, Manila.
- _____. 2004. *Key Areas of Economic Analysis of Projects: An Overview*. ADB, Manila.
- _____. 2005a. *Lao People's Democratic Republic: Greater Mekong Subregion Nam Theun 2 Hydroelectric Project. Report and Recommendation of the President*. ADB, Manila.
- _____. 2005b. *Viet Nam: Northern Power Transmission Expansion Sector Project. Report and Recommendation of the President*. ADB, Manila.
- _____. 2007. *Greater Mekong Subregion Southern Coastal Corridor Project. Report and Recommendation of the President*. ADB, Manila.
- _____. 2009. *People's Republic of China: Hebei Small Cities and Towns Development Demonstration Sector Project. Report and Recommendation of the President*. ADB, Manila.
- ADB, UNDP, and ESCAP. 2010. *Paths to 2015: MDG Priorities in Asia and the Pacific—Asia-Pacific MDG Report 2010/11*.
- Athukorala, P. P. A. W., H. M. Gunatilake, S. Dharmasena, L. H. P. Gunaratne, and J. Weerahewa. 2009. "Estimation of Household Demand for Electricity in Sri Lanka: A Co-integration Analysis." *Resources, Energy, and Development* 6(2):51–66.
- Atkinson, G., S. Dietz, and E. Neumayer. 2007. *Handbook of Sustainable Development*. Cheltenham: Edward Elgar.

- Banister, D., and J. Berechman. 2000. *Transport Investment and Economic Development*. London: UCL Press.
- Banks, J., R. Blundell, and A. Lewbell. 1997. "Quadratic Engel Curves and Consumer Demand." *Review of Economics and Statistics* 79(4):527–40.
- Barsky, R., M. Kimball, T. Juster, and M. Shapiro. 1995. *Preference Parameters and Behavioral Heterogeneity: An Experimental Approach in the Health and Retirement Survey*. NBER Working Paper No. 5213, National Bureau of Economic Research.
- Bartlett, J. E. II, J. W. Kotrlik, and C. Higgins. 2001. "Organizational Research: Determining Appropriate Sample Size in Survey Research." *Information Technology, Learning, and Performance Journal* 19(1):43–50.
- Baumol, W. 1968. "On the Social Rate of Discount." *American Economic Review* 58:788–802.
- Beckerman, W. and C. Hepburn. 2007. "Ethics of the Discount Rate in the Stern Review on the Economics of Climate Change." *World Economics* 8(1):187–210.
- Belli, P., J. R. Anderson, H. N. Barnum, J. A. Dixon, and J-P. Tan. 1998. *Handbook on Economic Analysis of Investment Operations*. World Bank, Washington, DC.
- . 2001. *Economic Analysis of Investment Operations: Analytical Tools and Practical Applications*. World Bank Institute, Washington, DC.
- Bergland, O., K. Magnussen, and S. Navrud. 1995. *Benefits Transfer: Testing for Accuracy and Reliability*. Discussion Paper 95–03, Department of Economics, Agricultural University of Norway.
- Berndt, E. R., and R. Samaniego. 1983. *Residential Electricity Demand in Mexico: A Model Distinguishing Access from Consumption*. Working Paper, Alfred P. Sloan School of Management.
- Beyer, J. 1975. "Estimating the Shadow Price of Foreign Exchange: An Illustration from India." *Journal of Development Studies* 11(4):302–15.
- Bishop, R. C., and T. A. Heberlein. 1979. "Measuring Values of Extra Market Goods: Are Indirect Measures Biased?" *American Journal of Agricultural Economics* 61(5):926–30.

- Blundell, R. 1988. "Consumer Behaviour: Theory and Empirical Evidence—A Survey." *Economic Journal* 98:16–65.
- Blundell, R., M. Browning, and C. Meghir. 1994. "Consumer Demand and the Life-Cycle Allocation of Household Expenditures." *Review of Economic Studies* 61:57–80.
- Blundell, R., P. Pashardes, and G. Weber. 1993. "What Do We Learn About Consumer Demand Patterns from Micro Data?" *American Economic Review* 83(3):570–97.
- Boardman, A. E., D. H. Greenberg, A. R. Vining, and D. L. Weimer. 1996. *Cost-Benefit Analysis: Concepts and Practice*. New Jersey: Prentice-Hall.
- _____. 2001. *Cost-Benefit Analysis: Concepts and Practice*, 2nd ed. Upper Saddle River, NJ: Prentice-Hall.
- Bolt, K., G. Ruta, and M. Sarraf. 2005. *Estimating the Cost of Environmental Degradation: A Training Manual in English, French and Arabic*. Environment Department Papers, World Bank, Washington, DC. Accessed from www.worldbank.org.
- Bosch, C., K. Hommann, G. Rubio, C. Sadoff, and L. Travers. 2000. "Water and Sanitation." *A Sourcebook for Poverty Reduction Strategies*, Volume 2. World Bank, Washington, DC.
- Boyle, K. J., and J. C. Bergstrom. 1992. "Benefit Transfer Studies: Myths, Pragmatism, and Idealism". *Water Resources Research* 28(3):657–63.
- Bradford, D. 1975. "Constraints on Government Investment Opportunities and the Choice of Discount Rate." *American Economic Review* 65(5):887–99.
- Brent, R. 2006. *Applied Cost-Benefit Analysis*. Cheltenham: Edward Elgar.
- Brookshire, D., and D. Whittington. 1993. "Water Resource Issues in the Developing Countries". *Water Resources Research* 29(7):1883–88.
- Brouwer, R., and F. A. Spaninks. 1999. "Validity of Environmental Transfer: Further Empirical Testing." *Environmental Resource Economics* 14:95–117.
- Brown, G. M. Jr. and R. Mendelsohn. 1984. "The Hedonic Travel Cost Method." *The Review of Economics and Statistics* 66(3):427–33.

- Browning, E. 1987. "On the Marginal Welfare Cost of Taxation." *American Economic Review* 77(1):11–23.
- Burgess, D. 1988. "Complementarity and the Discount Rate for Public Investment." *The Quarterly Journal of Economics* August 1988:527–41.
- Cameron, S. 2005. *Econometrics*, McGraw Hill.
- Cameron, T. A. 1988. "A New Paradigm for Valuing Non-market Goods Using Referendum Data: Maximum Likelihood Estimation by Censored Logistic Regression." *Journal of Environmental Economics and Management* 15:355–79.
- Cameron, T. A., G. L. Poe, R. G. Ethier, and W. D. Schulze. 2002. "Alternative Non-market Value-Elicitation Methods: Are the Underlying Preferences the Same?" *Journal of Environmental Economics and Management* 44(3):391–425.
- Cameron, T. A., and M. D. James. 1987. "Efficient Estimation Methods for 'Closed-Ended' Contingent Valuation Surveys." *Review of Economics and Statistics* 69(2):269–76.
- Carson, R. T. 2003. *Contingent Valuation: A Comprehensive Bibliography and History*. Cheltenham, UK and Northampton, MA: Edward Elgar.
- Caves, D., J. A. Herrigas, and R. Windle. 1990. "Customer Demand for Service Reliability in the Electric Power Industry: A Synthesis of the Outage Cost Literature." *Bulletin of Economic Research* 42(2):79–119.
- Champ, P. K. Boyle, and T. Brown, eds. 2003. *A Primer on Non-Market Valuation*. Dordrecht: Kluwer.
- Choe, K., D. Whittington, and D. T. Lauria. 1996. "The Economic Benefits of Surface Water Quality Improvements in Developing Countries: A Case Study of Davao, Philippines." *Land Economics* 72(4):519–37.
- Choynowski, P. 2002. *Measuring Willingness to Pay for Electricity*. Economics and Research Department Technical Note No. 3. ADB, Manila.
- Ciriacy-Wantrup, S. V. 1947. "Capital Returns from Soil Conservation Practices." *Journal of Farm Economics* 29:1181–96.

- Clarke, R. and A. Low. 1993. "Risk Analysis in Project Planning: A Simple Spreadsheet Application Using Monte Carlo Techniques." *Project Appraisal* 8(3):141–6.
- Cline, W. 1992. *The Economics of Global Warming*. Institute for International Economics, Washington, DC.
- _____. 2007. *Global Warming and Agriculture: Impact Estimates by Country*. Center for Global Development, Peterson Institute for International Economics, Washington, DC.
- Cowell, F., and K. Gardiner. 1999. *Welfare Weights*. STICERD Research Paper No. 20, London School of Economics, London.
- Cropper, M., W. N. Evans, S. J. Berard, M. M. Ducla-Soares, and P. R. Portney. 1992. "The Determinants of Pesticide Regulation: A Statistical Analysis of EPA Decision-making." *Journal of Political Economy* 100(1):175–97.
- Cropper, M., and D. Laibson. 1998. *The Implications of Hyperbolic Discounting for Project Evaluation*. World Bank Policy Research Working Paper Series 1943, Washington, DC.
- Cummings, R. R., D. S. Brookshire, and W. D. Schulze, eds. 1986. *Valuing Environmental Goods: An Assessment of the Contingent Valuation Method*. Totowa, NJ: Rowman Allanheld.
- Curry, S. and J. Weiss. 1990. *Project Analysis in Developing Countries*. London and Basingstoke: Macmillan.
- _____. 2000. *Project Analysis in Developing Countries*, second edition. London and Basingstoke: Macmillan.
- Dalenius, T. 1985. *Elements of Survey Sampling. Swedish Agency for Research Cooperation with Developing Countries*. Statistics Sweden, Stockholm.
- Damigos, D., C. Tourkoulis, and D. Diakoulaki. 2009. "Households' Willingness to Pay for Safeguarding Security of Natural Gas Supply in Electricity Generation." *Energy Policy* 37(5): 2008–17.
- Dasgupta, P. 2006. *Comments on the Stern Review's Economics of Climate Change*. Paper prepared for a seminar on the Stern Review's Economics of Climate Change at the Royal Society, 8 November, London.

- _____. 2008. "Discounting Climate Change." *Journal of Risk and Uncertainty* 37:141–69.
- Dasgupta, P., S. Marglin, and A. Sen. 1972. *Guidelines for Project Evaluation*. United Nations Industrial Development Organization, Vienna.
- Dasgupta, A., and D. Pearce. 1972. *Cost–Benefit Analysis*. UK: Palgrave Macmillan.
- Day, B. 2002. "Valuing Visits to Game Parks in South Africa." In D. Pearce, C. Pearce, and C. Palmer, eds. *Valuing the Environment in Developing Countries: Case Studies*. Cheltenham: Edward Elgar.
- De Jong, G. and H. Gunn. 2001 "Recent Evidence on Car Cost and Time Elasticities of Travel Demand in Europe." *Journal of Transport Economics and Policy* 35(2).
- Deaton, A. 1997. *The Analysis of Household Surveys: A Microeconomic Approach to Development Policy*. Baltimore, MD: Johns Hopkins University Press.
- Deininger, K., L. Squire, and S. Basu. 1998. "Does Economic Analysis Improve the Quality of Foreign Assistance?" *World Bank Economic Review* 12(3):385–418.
- Devarajan, S., L. Squire, and S. Suthiwart-Narueput. 1996. "Project Appraisal at the World Bank." In C. Kirkpatrick, and J. Weiss, eds. *Cost–Benefit Analysis and Project Appraisal in Developing Countries*. Cheltenham, UK: Edward Elgar.
- De Vita, G., K. Endresen, and L. C. Hunt. 2006. "An Empirical Analysis of Energy Demand in Namibia." *Energy Policy* 34:3447–63.
- Devicienti, F., I. Klytchnikova, and S. Paternostro. 2004. *Willingness to Pay for Water and Energy: An Introductory Guide to Contingent Valuation and Coping Cost Techniques*. Energy Working Notes. World Bank, Washington, DC.
- Diamond, P. 1968. "Opportunity Cost of Public Investment: Comment." *Quarterly Journal of Economics* 84:682–8.
- Diamond, P., and J. Mirrlees. 1971a. "Optimal Taxation and Public Production I: Production Efficiency." *American Economic Review* 61:8–27.
- _____. 1971b. "Optimal Taxation and Public Production II: Tax Rules." *American Economic Review* 61:261–78.

- Dinwiddy, C. and F. Teal. 1995. *Principles of Cost-Benefit Analysis for Developing Countries*. Cambridge: Cambridge University Press.
- Dixit, A. and R. Pindyck. 1994. *Investment Under Uncertainty*. Princeton: Princeton University Press.
- Dole, D. 2003. *Setting User Charges for Public Services: Policies and Practice at the Asian Development Bank*. ERD Technical Note Series No. 9, Economics and Research Department, Asian Development Bank, Manila.
- Dole, D., and I. Bartlett. 2004. *Beyond Cost Recovery: Setting User Charges for Financial, Economic, and Social Goals*. ERD Technical Note Series No. 10, Economics and Research Department, Asian Development Bank, Manila
- Dole, D., and E. Balucan. 2006. *Setting User Charges for Urban Water Supply: A Case Study of the Metropolitan Cebu Water District in the Philippines*. ERD Technical Note Series No. 17, Economics and Research Department, Asian Development Bank, Manila.
- Donatos, G. S., and G. J. Mergos. 1991. "Residential Demand for Electricity: The Case of Greece." *Energy Economics* 13(1):41–47.
- Downing, M., and T. Ozuna, Jr. 1996. "Testing the Reliability of the Benefit Function Transfer Approach." *Journal of Environmental Economics and Management* 30:316–22.
- Eales, R., S. Smith, C. Twigger-Ross, W. Sheate, E. Özdemiroglu, C. Fry, P. Tomlinson, and C. Foan. 2005. "Emerging Approaches to Integrated Appraisal in the UK." *Impact Assessment and Project Appraisal* 23(2):113–23.
- Eckstein, O. 1961. "A Survey of the Theory of Public Expenditure and Criteria." In J. Buchanan, ed., *Public Finance: Needs, Sources and Utilization*. Princeton, NJ: Princeton University Press.
- Edwards, S. 1986. "Country Risk, Foreign Borrowing and the Social Discount Rate in an Open Developing Economy." *Journal of International Money and Finance* 5:S79–S96.
- ESMAP. 2003. *Rural Electrification and Development in the Philippines: Measuring the Social and Economic Benefits*. ESMAP Report 255/03. World Bank, Washington, DC.

- Espey, J. A., and M. Espey. 2004. "Turning on the Lights: A Meta-analysis of Residential Electricity Demand Elasticities." *Journal of Agricultural and Applied Economics* 36:1:65–81.
- Estache, A., Foster, V., and Q. Wodon. 2002. *Accounting for Poverty in Infrastructure Reform: Learning from Latin America's Experience*. WBI Development Studies No. 23950, World Bank, Washington DC.
- Eto, J., J. Koomey, B. Lehman, N. Martin, E. Mills, C. Webber, and E. Worrell. 2001. *Scoping Study on Trends in the Economic Value of Electricity Reliability to the U.S. Economy*. Technical Report, Lawrence Berkeley Laboratory, Berkeley, California: Energy Analysis Department.
- European Commission. 1997. *Manual: Financial and Economic Analysis of Development Projects*. Commission of the European Communities, Brussels.
- _____. 2006. *Guidance on the Methodology for Carrying Out Cost-Benefit Analysis*. Working Document No. 4: The New Programming Period 2007–2013, Brussels. Available: http://ec.europa.eu/regional_policy/sources/docoffic/2007/working/wd4_cost_en.pdf.
- _____. 2008. *Guide to Cost-Benefit Analysis of Investment Projects: Structural Funds, Cohesion Fund and Instrument for Pre-Accession*. Directorate General Regional Policy, European Commission.
- Evans, D. 2004a. "The Elevated Status of the Elasticity of Marginal Utility of Consumption." *Applied Economics Letters* 11:443–7.
- _____. 2004b. "A Social Discount Rate for France." *Applied Economics Letters* 11:803–808.
- _____. 2005. "The Elasticity of Marginal Utility of Consumption: Estimates for 20 OECD Countries." *Fiscal Studies* 26(2):197–224.
- _____. 2006. *Social Discount Rates for the European Union*. Working Paper No. 2006–20, Fifth Milan European Economy Workshop, Università degli Studi di Milano, Italy.
- Evans, D., and H. Sezer. 2002. "A Time Preference Measure of the Social Discount Rate for the UK." *Applied Economics Letters* 34:1925–34.
- _____. 2004. "Social Discount Rates for Six Major Countries." *Applied Economics Letters* 11:557–60.

- Evans, D., E. Kula, and H. Sezer. 2005. "Regional Welfare Weights for the UK: England, Scotland, Wales and Northern Ireland." *Regional Studies* 39:923–37.
- Feldstein, M. 1972. "The Inadequacy of Weighted Discount Rates." In R. Layard, ed., *Cost–Benefit Analysis*. Middlesex, UK: Penguin Books.
- Fewtrell, L., R. B. Kaufmann, D. Kay, W. Enanoria, L. Haller, and J. M. Colford. 2005. "Water, Sanitation, and Hygiene Interventions to Reduce Diarrhea in Less Developed Countries: A Systematic Review and Meta-Analysis." *Lancet Infectious Diseases* 5(1):42–52.
- Filippini, M., and S. Pachauri. 2004. "Elasticities of Electricity Demand in Urban Indian Households." *Energy Policy* 32:429–36.
- Francisco, C. R. 1988. *Demand for Electricity in the Philippines: Implications for Alternative Electricity Pricing Policies*. Philippine Institute for Development Studies.
- Freeman III, A. M. 1993. *The Measurement of Environmental and Resource Values: Theory and Methods*. Washington, DC: Resources for the Future.
- _____. 2003. *The Measurement of Environmental and Resource Values: Theory and Methods*. 2nd edition. Resources for the Future.
- Fujimura, M., and J. Weiss. 2000. *Integration of Poverty Impact in Project Economic Analysis*. EDRC Methodology Series No. 2. ADB, Manila.
- Glapke, E., and R. Fazzolare. 1985. "Economic Demand Analysis for Electricity in West Africa." *The Energy Journal* 6(1):137–44.
- Goodwin, P. J., J. Dargay, and M. Hanly 2004. "Elasticities of Road Traffic and Fuel Consumption with Respect to Price and Income: A Review" *Transport Reviews* 24(3).
- Griffin, C. C., J. Briscoe, B. Singh, R. Ramasubban, and R. Bhatia. 1995. "Contingent Valuation and Actual Behavior: Predicting Connections to New Water Systems in the State of Kerala, India." *The World Bank Economic Review* 9(3):373–95.
- Grosh, M., and J. Muñoz. 1996. *A Manual for Planning and Implementing the Living Standards Measurement Study Surveys*. LSMS Working Paper No. 126, World Bank, Washington, DC.

- Gunatilake, H. 2003. *Environmental Valuation: Theory and Applications*. Postgraduate Institute of Agriculture, University of Peradeniya, Peradeniya, Sri Lanka.
- Gunatilake, H., J-C. Yang, S. K. Pattanayak, and C. van den Berg. 2006. *Willingness to Pay and Design of Water Supply and Sanitation Projects: A Good Practice Case Study*. ERD Technical Note No. 19, Economics and Research Department, Asian Development Bank. Manila.
- Gunatilake, H., J-C. Yang, S. K. Pattanayak, and K. A. Choe. 2007. *Good Practices for Estimating Reliable Willingness-to-Pay Values in the Water Supply and Sanitation Sector*. ERD Technical Note No. 23, Economics and Research Department, Asian Development Bank. Manila.
- Gunatilake, H., and M. J. Carangal-San Jose. 2008. *Privatization Revisited: Lessons from Private Sector Participation in Water Supply and Sanitation in Developing Countries*. ADB Economics Working Paper Series No. 115, Asian Development Bank, Manila.
- Gwilliam, K. 1997. "The Value of Time in Economic Evaluation of Transport Projects." *Infrastructure Note OT-5*.
- Hanemann, W. M. 1984. "Welfare Evaluations in Contingent Valuation Experiments with Discrete Responses." *American Journal of Agricultural Economics* 66(3):332–41.
- Harberger, A. 1972. *Project Evaluation: Collected Papers*. Chicago: The University of Chicago Press.
- _____. 1978. "On the Use of Distributional Weights in Social Cost-Benefit Analysis." *Journal of Political Economy* 86(2):87–120.
- Harberger, A., and G. Jenkins. 2002. *Cost-Benefit Analysis for Investment Decisions*. Queen's University, Canada.
- Harrod, R. 1948. *Towards a Dynamic Economics*. London: Macmillan.
- Hartman, R. 1990. "One Thousand Points of Light Seeking a Number: A Case Study of CBO's Search for a Discount Rate Policy." *Journal of Environmental Economics and Management* 18(2):S3–S7.
- HEATCO. 2006. *Developing Harmonised European Approaches for Transport Costing and Project Assessment*. European Union, Brussels.

- Henderson, N., and I. Bateman. 1995. "Empirical and Public Choice Evidence for Hyperbolic Social Discount Rates and the Implications for Intergenerational Discounting." *Environmental and Resource Economics* 5:413–23.
- Henderson, N., and I. Langford. 1998. "Cross-Disciplinary Evidence for Hyperbolic Social Discount Rates." *Management Science* 44(11):1493–500.
- HM Treasury. 2003. *The Green Book: Appraisal and Evaluation in Central Government*. HM Treasury. London.
- _____. 2008. *The Green Book: Appraisal and Evaluation in Central Government*. HM Treasury. London. Accessed from www.hm-treasury.gov.uk.
- Holtedahl, P., and F. L. Joutz. 2004. "Residential Electricity Demand in [Taipei,China]." *Energy Economics* 26:201–24.
- Hondroyannis, G. 2004. "Estimating Residential Demand for Electricity in Greece." *Energy Economics* 26(3):319–34.
- Hotelling, H. 1949. Letter to Newton B. Drury, National Parks Service (dated June 18, 1947). *The Economics of Public Recreation: An Economic Study of the Monetary Evaluation of Recreation in the National Parks*. Land and Recreational Planning Division, National Park Service, Washington, DC. Processed.
- Irvin, G. 1978. *Modern Cost-Benefit Methods*. London and Basingstoke: Macmillan.
- Jenkins, G. 1997. "Project Analysis and the World Bank." *American Economic Review* 87(2):38–42.
- Jones, L., P. Tandon, and I. Vogelsan. 1990. *Selling Public Enterprises: A Cost-Benefit Methodology*. Cambridge: MIT Press.
- Kalton, G. 1983. *Introduction to Survey Sampling*. Quantitative Applications in the Social Sciences Series No. 35. Thousand Oaks, CA: Sage Publications.
- Kay, J. 1972. "Social Discount Rates." *Journal of Public Economics* 1:359–78.
- Kirchhoff, S., B. G. Colby, and J. T. LaFrance. 1997. "Evaluating the Performance of Benefit Transfer: An Empirical Inquiry." *Journal of Environmental Economics and Management* 33: 75–93.

- Kopp, R., and P. Portney. 1999. "Mock Referenda for Intergenerational Decision Making." In P. Portney and J. Weyant, eds., *Discounting and Intergenerational Equity*. Resources for the Future, Washington, DC.
- Koundouri, P., Y. Kountouris, and K. Remounou. 2009. "Valuing a Wind Farm Construction: A Contingent Valuation Study in Greece." *Energy Policy* 37(5):1939–44.
- KPMG. 2004. *Corporate Tax Rates Survey*. Klynveld, Peat, Marwick, Goerdeler International, Switzerland. Available: http://www.us.kpmg.com/microsite/Global_Tax/CTR_Survey/2004CTRS.pdf.
- Krupnick, A. J. 1993. *Benefit Transfers and Valuation of Environmental Improvements*. *Resources* Winter (110):1–6.
- Kula, E. 1984. "Derivation of Social Time Preference Rates for the United States and Canada." *The Quarterly Journal of Economics* November 1984:873–82.
- _____. 1985. "An Empirical Investigation on the Social Time Preference Rate for the UK." *Environment and Planning* 17:199–217.
- _____. 1987. "Social Interest Rate for Public Sector Project Appraisal in the UK, USA and Canada." *Project Appraisal* 2:169–74.
- _____. 2004. "Estimation of a Social Rate of Interest for India." *Journal of Agricultural Economics* 55(1):91–9.
- Lal, D. 1980. *Prices for Planning: Towards the Reform of Indian Planning*. London: Heinemann.
- Lampietti, J., et al. 2004. *Azerbaijan Household Energy Survey: Survey Documentation*. World Bank, Washington, DC. Processed.
- Lauria, D. T., D. Whittington, K. A. Choe, C. Turingan, and V. Abiad. 1999. "Household Demand for Improved Sanitation Services: A Case Study of Calamba, the Philippines." In Bateman, I. and K. Willies, eds., *Valuing Environmental Preferences: Theory and Practice of the Contingent Valuation Method in the US, EU, and Developing Countries*. Oxford: Oxford University Press.
- Leggett, C. G., and N. E. Bockstael. 2000. "Evidence of the Effects of Water Quality on Residential Land Prices." *Journal of Environmental Economics and Management* 39:121–44.

- Lesser, J., and R. Zerbe. 1995. "What Can Economic Analysis Contribute to the Sustainability Debate?" *Contemporary Economic Policy* 13(3):88–100.
- Lind, R. 1982. "A Primer on the Major Issues Relating to the Discount Rate for Evaluating National Energy Option." In R. Lind, ed., *Discounting for Time and Risk in Energy Policy*. Resources for the Future, Washington, DC.
- _____. 1990. "Reassessing the Government's Discount Rate Policy in Light of New Theory and Data in a World Economy with a High Degree of Capital Mobility." *Journal of Environmental Economics and Management* 18:S8–S28.
- _____. 1997. "Intertemporal Equity, Discounting, and Economic Efficiency in Water Policy Evaluation." *Climatic Change* 37:41–62.
- Litman, T. 2009. *Transportation Elasticities TDM Encyclopedia*. Victoria Transport Policy Institute mimeo. Available: www.vtppi.org.
- Little, I. and J. Mirrlees. 1969. *Manual of Industrial Project Analysis in Developing Countries*. Vol. 2. Organisation for Economic Co-operation and Development, Paris
- _____. 1974. *Project Appraisal and Planning for Developing Countries*. London: Heinemann.
- _____. 1994. "The Costs and Benefits of Analysis: Project Appraisal and Planning Twenty Years On." In R. Layard and S. Glaister, eds. *Cost-Benefit Analysis*, 2nd edition. Cambridge: Cambridge University Press.
- Londero, E. 1996. *Benefits and Beneficiaries: An Introduction to Estimating Distributional Effects in Cost-Benefit Analysis*. 2nd edition. Inter-American Development Bank, Washington DC.
- _____. 2003. *Shadow Prices for Project Appraisal: Theory and Practice*. Cheltenham: Edward Elgar.
- Loomis, J. B. 1992. "The Evolution of a More Rigorous Approach to Benefit Transfer: Benefit Function Transfer." *Water Resources Research* 28(3):701–5.

- Loomis, J. B., and D. S. White. 1995. *Economic Benefits of Rare and Endangered Species: Summary and Meta Analysis*. Working Paper, Department of Agricultural and Resource Economics, Colorado State University.
- Lyon, R. 1990. "Federal Discount Rate Policy, the Shadow Price of Capital, and Challenges for Reforms." *Journal of Environmental Economics and Management* 18:S29–S50.
- Marglin, S. 1963a. "The Opportunity Costs of Public Investment." *The Quarterly Journal of Economics* 77(2):274–89.
- . 1963b. "The Social Rate of Discount and the Optimal Rate of Investment." *The Quarterly Journal of Economics* 77(1):95–111.
- Markandya, A. and D. Pearce. 1994. "Natural Environments and the Social Rate of Discount." In J. Weiss, ed. *The Economics of Project Appraisal and the Environment*. Aldershot: Edward Elgar.
- Mishan, E. 1967. "Criteria for Public Investment: Some Simplifying Suggestions." *Journal of Political Economy* 75:139–46.
- Mitchell, R. C., and R. T. Carson. 1989. *Using Surveys to Value Public Goods: The Contingent Valuation Method*. Baltimore: Johns Hopkins University Press.
- Moore, M., A. Boardman, A. Vining, D. Weimer, and D. Greenberg. 2004. "'Just Give Me a Number!' Practical Values for the Social Discount Rate." *Journal of Policy Analysis and Management* 23(4):789–812.
- Mu, X., D. Whittington, and J. Briscoe. 1990. "Modeling Village Water Demand Behaviour. A Discrete Choice Approach." *Water Resources Research* 26:521–29.
- Munasinghe, M. 1990. *Electric Power Economics: Selected Works*. London: Butterworths.
- Munoz, J. 2003. "A Guide for Data Management of Household Surveys." In United Nations, *The Analysis of Operating Characteristics of Surveys in Developing Countries*. United Nations, New York.
- Murray, C. 1994. "Quantifying the Burden of Disease: The Technical Basis for Disability Adjusted Life Years." In I. C. Murray and A. Lopez, eds. *Global Comparative Assessment in the Health Sector*. World Health Organization, Geneva.

- Murray, C. and A. Lopez, eds. 1996. *The Global Burden of Disease*. Harvard School of Public Health, Boston, MA.
- National Development and Reform Commission. 2002. *Guidelines for the Preparation of Feasibility Study of Investment Projects*. Beijing: NDRC.
- _____. 2006. *The Economic Analysis of Construction Projects: Methods and Parameters*, 3rd version. Beijing: NDRC. Processed.
- Nauges, C., and C. van den Berg. 2006. *Water Markets, Demand, and Cost Recovery for Piped Water Supply Services: Evidence from Southwest Sri Lanka*. World Bank Policy Research Working Paper No. 3941, World Bank, Washington, DC.
- Nellthorp, J., and G. Hyman. 2001. *Alternatives to the Rule of Half in Matrix Based Appraisal*. Report to the UK Government, Department of the Environment, Transport and the Regions.
- Newbery, D. 1992. *Long-Term Discount Rates for the Forest Enterprise*. Paper commissioned by The Department of Forestry, Forestry Commission, Edinburgh.
- Nordhaus, W. 1993. "Rolling the 'DICE': An Optimal Transition Path for Controlling Greenhouse Gases." *Resource and Energy Economics* 15:27–50.
- _____. 1994. *Managing The Global Commons: The Economics of Climate Change*. Cambridge, MA: The MIT Press.
- _____. 1999. "Discounting and Public Policies that Affect the Distant Future." In P. Portney, and J. Weyant, eds., *Discounting and Intergenerational Equity*. Resources for the Future, Washington, DC.
- _____. 2006. *The Stern Review on the Economics of Climate Change*. NBER Working Paper No. W12741, National Bureau of Economic Research.
- O'Doherty, R. K. 1996. *Contingent Valuation and Benefit Transfer: An Assessment in a Local Planning Context*. Working Papers in Economics No. 19, Faculty of Economics and Social Science, University of the West of England, Bristol.

- O'Garra, T., S. Mourato, L. Garrity, P. Schmidt, A. Beerenwinkel, M. Altmann, D. Hart, C. Graesel, and S. Whitehouse. 2007. "Is the Public Willing to Pay for Hydrogen Buses? A Comparative Study of Preferences in Four Cities." *Energy Policy* 35(7):3630–42.
- Overseas Development Agency (ODA). 1988. *Appraisal of Projects in Developing Countries. A Guide for Economists*, 3rd edition. London: HMSO.
- OXERA. 2002. *A Social Time Preference Rate for Use in Long-Term Discounting*. Report for the Office of the Deputy Prime Minister, Department for Transport, and Department of the Environment, Food and Rural Affairs, Oxford Economic Research Associates, Ltd., Oxford, UK.
- Parsons, G. R., and M. J. Kealy. 1994. "Benefits Transfer in a Random Utility Model of Recreation." *Water Resources Research* 30(8):2477–84.
- Pattanayak, S. K., J.-C. Yang, C. Agarwal, H. M. Gunatilake, H. M. S. J. H. Bandara, and T. Ranasinghe. 2004a. *Water, Sanitation and Poverty in Southwest Sri Lanka*. RTI International, Durham, NC.
- _____. 2004b. *Water Sanitation and Poverty in Southwest Sri Lanka: Revised Final Report*. The World Bank, Washington, DC.
- Pattanayak, S. K., and J.-C. Yang. 2002. *Distributional Incidence of Water Tariffs and Subsidies in Kathmandu, Nepal*. RTI International, Durham, NC.
- Pattanayak, S. K., J.-C. Yang, D. Whittington, and K. C. Bal Kumar. 2005. "Coping with Unreliable Public Water Supplies: Averting Expenditures by Households in Kathmandu, Nepal." *Water Resources Research* 41(2).
- Pattanayak, S. K., C. van den Berg, J.-C. Yang, and G.L. Van Houtven. 2006. *The Use of Willingness to Pay Experiments: Estimating Demand for Piped Water Connections in Sri Lanka*. *World Bank Policy Research Working Paper No. 3818*, World Bank, Washington, DC.
- Pearce, D., B. Groom, C. Hepburn, and C. Kounduri. 2003. "Valuing the Future: Recent Advances in Social Discounting." *World Economics* 4:121-141.

- Pearce, D., and D. Ulph. 1995. *A Social Discount Rate for the United Kingdom*. CSERGE Working Paper GEC 95-01, Centre for Social and Economic Research on the Global Environment, University of East Anglia, Norwich, UK.
- _____. 1999. "A Social Discount Rate for the United Kingdom." In D. Pearce, ed., *Environmental Economics: Essays in Ecological Economics and Sustainable Development*. Cheltenham: Edward Elgar Publishing.
- Pearce, D., G. Atkinson, and S. Mourato. 2006. *Cost-Benefit Analysis and the Environment: Recent Developments*. Organisation for Economic Co-operation and Development, Paris.
- Penn World Tables 6.1*. Available: http://pwt.econ.upenn.edu/php_site/pwt61_form.php.
- Percoco, M. 2008. "A Social Discount Rate for Italy." *Applied Economics Letters, Taylor and Francis Journals* 15(1):73-7.
- Perkins, F. 1994. *Practical Cost Benefit Analysis: Basic Concepts and Applications*. Melbourne: MacMillan Education Australia.
- Pesaran, M. H., and T. Akiyama. 1998. *Energy Demand in Asian Developing Economies*. USA: Oxford University Press.
- PIARC. *The Highway Development and Management Model (HDM4) Documentation and Software*. Available: <http://hdm4.piarc.org/>.
- Pigou, A. 1932. *The Economics of Welfare*. London: Macmillan.
- Portney, P. R. 1994. "The Contingent Valuation Debate: Why Economists Should Care." *Journal of Economic Perspectives* 8(4):3-17.
- Potts, D. 2002. *Project Planning and Analysis for Development*. Boulder: Lynne Rienner.
- Pouliquen, L. 1970. *Risk Analysis in Project Appraisal*. World Bank Staff Occasional Paper No. 11. Baltimore: The Johns Hopkins University Press.
- Powers, T., ed. 1981. *Estimating Accounting Prices for Project Appraisal*. Inter-American Development Bank, Washington, DC.
- Quinet, E., and R. Vickerman. 2004. *Principles of Transport Economics*. Edward Elgar Publishing.

- Ramcharran, H. 1990. "Electricity Consumption and Economic Growth in Jamaica." *Energy Economics* 12(1):65–70.
- Ramsey, F. 1928. "A Mathematical Theory of Saving." *Economic Journal* 38:543–59.
- Ray, A. 1984. *Cost-Benefit Analysis*. Baltimore, MD: Johns Hopkins University Press.
- Rayner, N., A. Lagman-Martin, and K. Ward. 2002. *Integrating Risk into ADB's Economic Analysis of Projects*. ERD Technical Note No. 2. Economics and Research Department. ADB, Manila.
- Rea, L. M., and R. A. Parker. 1997. *Designing and Conducting Survey Research: A Comprehensive Guide*. 2nd ed. San Francisco, CA: Jossey-Bass Publishers.
- Reutlinger, S. 1970. *Techniques for Project Appraisal under Uncertainty*. World Bank Staff Occasional Paper No. 10. Baltimore: The Johns Hopkins University Press.
- Rose, D. 2006. *The Public Sector Discount Rate*. Paper presented at the New Zealand Association of Economists Annual Conference, 26 June, Christchurch, New Zealand.
- Saerbeck, R. 1989. *Semi-Input-Output Analysis to Estimate National Economic Parameters: An Application to Botswana*. United Nations Industrial Development Organization, New York.
- Sandmo, A., and J. Drèze. 1971. "Discount Rates for Public Investments in Closed and Open Economies." *Economica* 38:395–412.
- Sanghvi, A., R. Vernstrom, and J. Besant-Jones. 1989. *Review and Evaluation of Historic Electricity Forecasting Experience, 1960–1985*. Industry and Energy Department Working Paper, Energy Series Paper No. 18, World Bank, Washington, DC.
- Savvides, S. 1994. "Risk Analysis in Investment Appraisal." *Project Appraisal* 9(1):3–18.
- Schelling, T. 1995. "Intergenerational Discounting." *Energy Policy* 23(4–5):395–401.
- Scott, K, D. Steele, and T. Temesgen. 2005. *Living Standards Measurement Study Surveys*. In United Nations, Household Sample Surveys in Developing and Transition Countries (ST/ESA/STAT/SER.F/96), United Nations Technical Report, New York.

- Scott, M. 1977. "The Test Rate of Discount and Changes in Base Level Income in the United Kingdom." *The Economic Journal* 87(346):219–41.
- _____. 1989. *A New View of Economic Growth*. Oxford, UK: Clarendon Press.
- Scott, M., J. D. MacArthur, and D. M. G. Newbery. 1976. *Project Appraisal in Practice*. London: Heinemann.
- Sen, A. 1961. "On Optimizing the Rate of Saving." *Economic Journal* 71:479–96.
- Shapiro, S. A. and C. H. Schroeder 2008. "Beyond Cost–Benefit Analysis: A Pragmatic Reorientation". *Harvard Environmental Law Review*, Volume 31; Wake Forest University Legal Studies Paper No. 1087796.
- Silva, P. and S. Pagiola, 2003. *A Review of the Valuation of Environmental Costs and Benefits in World Bank Projects*. World Bank, Environmental Economic Series Paper No. 94, Washington, DC.
- Smith, V. K. 2006. "Fifty Years of Contingent Valuation." In A. Alberini, and J. R. Kahn, eds., *Handbook on Contingent Valuation*. Cheltenham, UK: Edward Elgar Publishing.
- Solow, R. 1974. "Intergenerational Equity and Exhaustible Resources." *Review of Economic Studies* 41:29–45.
- Spackman, M. 2004. "Time Discounting and of the Cost of Capital in Government." *Fiscal Studies* 25(4):467–518.
- _____. 2006. *Social Discount Rates for the European Union: An Overview*. Working Paper No. 2006–33, Fifth Milan European Economy Workshop, Universita degli Studi di Milano, Italy. Available: http://www.economia.unimi.it/uploads/wp/SPACKMAN-2006_33.pdf.
- Squire, L. and H. van der Tak. 1975. *Economic Analysis of Projects*. Baltimore, MD: Johns Hopkins University Press.
- Stern, N. 2006. *The Economics of Climate Change: The Stern Review*. Cambridge, UK: Cambridge University Press.
- _____. 2007. *The Economics of Climate Change: The Stern Review*. Cambridge: Cambridge University Press.

- Stiglitz, J. 1994. "Discount Rates: the Rate of Discount for Cost-Benefit Analysis and the Theory of the Second Best." In R. Layard, and S. Glaister, eds., *Cost-Benefit Analysis*. Cambridge University Press.
- Toman, M. 1999. "Reconciling Philosophy and Economics in Long Term Discounting." In P. Portney, and J. Weyant, eds., *Discounting and Intergenerational Equity*. Resources for the Future, Washington, DC.
- UNDP. 2006. *Beyond Scarcity: Power, Poverty and the Global Water Crisis: Human Development Report 2006*. United Nations Development Programme, New York.
- UNIDO. 1972. *Guidelines for Project Evaluation*. United Nations Industrial Development Organization, New York.
- _____. 1978. *A Guide to Practical Project Appraisal*. United Nations International Development Organization, New York.
- _____. 1980. *Practical Appraisal of Industrial Projects*. United Nations Industrial Development Organization, New York.
- US Environmental Protection Agency. 2000. *Guidelines for Preparing Economic Analyses*. Washington, DC. Available: <http://yosemite.epa.gov/ee/epa/erm.nsf/vwRepNumLookup/EE-0228C?OpenDocument>.
- US General Accounting Office. 1991. *Discounting Policy*. Washington, DC.
- US Office of Management and Budget. 2003. *Circular No. A-94: Guidelines and Discount Rates for Benefit-Cost Analysis of Federal Programs*. Washington, DC.
- van den Berg, C., S. K. Pattanayak, J.-C. Yang, and H. Gunatilake. 2006. *Getting the Assumptions Right: Private Sector Participation Transaction Design and the Poor in Southwest Sri Lanka*. Water Supply and Sanitation Sector Board Discussion Paper Series Paper No. 7, World Bank, Washington, DC.
- Vossler, C. A., and J. Kerkvliet. 2003. "A Criterion Validity Test of the Contingent Valuation Method: Comparing Hypothetical and Actual Voting Behavior for a Public Referendum." *Journal of Environmental Economics and Management* 45:631–49.
- Ward, W. and B. Deren. 1991. *The Economics of Project Analysis: A Practitioner's Guide*. Economic Development Institute, World Bank, Washington, DC.

- Warr, P. 2006. "Roads and Poverty Reduction in Lao PDR." In J. Weiss, and H. A. Khan, eds. *Poverty Strategies in Asia*. Edward Elgar Publishing.
- Webb, M. and D. Pearce. 1985. *Economic Benefits of Power Supply*. Energy Department Paper No. 25. World Bank, Washington, DC.
- Weiss, J. 1979. "Project Selection and Equity Objective: The Use of Social Cost-Benefit Analysis in Pakistan." *Pakistan Development Review* 18(2).
- Weiss, J. 1988. "An Introduction to Shadow Pricing in a Semi-Input-Output Approach." *Project Appraisal* 3(4):181-89.
- _____. 1996. "Project Failure: The implications of a 25 Percent Rule." In C. Kirkpatrick and J. Weiss, eds. *Cost-Benefit Analysis and Project Appraisal in Developing Countries*. Cheltenham, UK: Edward Elgar.
- Weitzman, M. 1994. "On the Environmental Discount Rate." *Journal of Environmental Economics and Management* 26(2):200-09.
- _____. 1998. "Why the Far-Distant Future Should be Discounted at its Lowest Possible Rate." *Journal of Environmental Economics and Management* 36(3):201-08.
- _____. 2001. "Gamma Discounting." *American Economic Review* 91(1):261-71.
- Westley, G. D. 1992. *New Directions in Econometric Modeling of Energy Demand*. Interamerican Development Bank: Johns Hopkins University Press.
- Whitehead, J. C. 2006. "A Practitioner's Primer on Contingent Valuation." In A. Alberini, and J. R. Kahn, eds., *Handbook on Contingent Valuation*. Cheltenham, UK: Edward Elgar Publishing.
- Whitehead, J. C., and G. Blomquist. 2006. "The Use of Contingent Valuation in Benefit-Cost Analysis." In A. Alberini, and J. R. Kahn, eds., *Handbook on Contingent Valuation*. Cheltenham, UK: Edward Elgar Publishing.
- Whittington, D. 1988. *Guidelines for Conducting Willingness-to-Pay Studies for Improved Water Services in Developing Countries*. WASH Technical Report No. 56, USAID Water and Sanitation for Health Project, Washington, DC.

- _____. 1998. "Administering Contingent Valuation Surveys in Developing Countries." *World Development* 26(1):21–30.
- _____. 2002a. "Behavioural Studies of the Domestic Demand for Water Services in Africa: A Reply to Stephen Merrett." *Water Policy* 4:83–88.
- _____. 2002b. "Improving the Performance of Contingent Valuation Studies in Developing Countries." *Environmental and Resource Economics* 22(11):323–67.
- Whittington, D., D. Lauria, and X. Mu. 1991. "A Study of Water Vending and Willingness to Pay for Water in Onitsha, Nigeria." *World Development* 19(2/3):178–98.
- Whittington, D., S. K. Pattanayak, J. C. Yang, and K. C. B. Kumar. 2002. "Do Households Want Improved Piped Water Services? Evidence from Nepal." *Water Policy* 4(6):531–56.
- Willig, R. D. 1976. "Consumer's Surplus without Apology." *American Economic Review* 66:785–97.
- World Bank. 2005a. *Distribution of Benefits and Impacts on Poor People*. Notes on the Economic Evaluation of Transport Projects No. TRN-26.
- _____. 2005b. *Treatment of Induced Traffic*. Notes on the Economic Evaluation of Transport Projects No. TRN-11. Transport Economics, Policy and Poverty Thematic Group.
- _____. 2005c. *Valuation of Time Savings*. Notes on the Economic Evaluation of Transport Projects No. TRN-15. Transport Economics, Policy and Poverty Thematic Group.
- _____. 2005d. *Valuation of Accident Reduction*. Notes on the Economic Evaluation of Transport Projects No. TRN-16. Transport Economics, Policy and Poverty Thematic Group.
- _____. 2010. *Cost-Benefit Analysis in World Bank Projects*. Independent Evaluation Group, World Bank, Washington, DC.
- Yang, J., S. Pattanayak, F. R. Johnson, Ca. Mansfield, C. van den Berg, and K. Jones. 2006. *Unpackaging Demand for Water Service Quality: Evidence from Conjoint Surveys in Sri Lanka*. World Bank Policy Research Working Paper No. 3817, World Bank, Washington, DC.

- Zerbe, Jr., R. 2005. "Should Moral Sentiments Be Incorporated into Benefit-Cost Analysis? An Example of Long-Term Discounting." *Policy Sciences* 37(3-4):305-18.
- Zerbe, Jr., R., and D. Dively. 1994. *Benefit-Cost Analysis: In Theory and Practice*. New York: Harper Collins.
- Zhuang, J., Z. Liang, T. Lin, and F. de Guzman. 2007. *Theory and Practice in the Choice of Social Discount Rate for Cost-Benefit Analysis: A Survey*. ERD Working Paper No. 94, Economics and Research Department, Asian Development Bank. Manila.
- Ziramba, E. 2008. "The Demand for Residential Electricity in South Africa." *Energy Policy* 36(9):3460-66.
- Zwerina, K., J. Huber, and W. F. Kuhfield. 1996. *A General Method for Constructing Efficient Choice Designs*. SAS Working Paper, Fuqua School of Business, Duke University, Durham, NC. Available: <http://support.sas.com/techsup/technote/ts722e.pdf>.

Cost-Benefit Analysis for Development: A Practical Guide

The Asian Development Bank (ADB) has been continuously undertaking measures to enhance the effectiveness of its operations. To improve projects both at the preparation and implementation stages, ADB issued the *Guidelines for Economic Analysis of Projects* in 1997 as a means to enhancing project quality at entry. The conduct of proper economic analysis helps ensure the efficient use of development funds and public resources and thereby increase aid effectiveness.

This practical guide is a supplement to the *Guidelines for the Economic Analysis of Projects*. It provides an overview of recent methodological developments in cost-benefit analysis as well as suggested improvements in the economic analysis of projects in selected sectors through case studies. These case studies illustrate the application of suggested methodologies, taking into account sector-specific needs, as well as difficulties faced by practitioners in terms of data and time constraints during project processing. It also aims to contribute to ADB's capacity building initiatives as this will be the main reference material for conduct of economic analysis.

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ADB's vision is an Asia and Pacific region free of poverty. Its mission is to help its developing member countries reduce poverty and improve the quality of life of their people. Despite the region's many successes, it remains home to two-thirds of the world's poor: 1.7 billion people who live on less than \$2 a day, with 828 million struggling on less than \$1.25 a day. ADB is committed to reducing poverty through inclusive economic growth, environmentally sustainable growth, and regional integration.

Based in Manila, ADB is owned by 67 members, including 48 from the region. Its main instruments for helping its developing member countries are policy dialogue, loans, equity investments, guarantees, grants, and technical assistance.

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