PN-AAL-627

622112

Gordway

WORKBOOK

Quantitative Procedures and Applications

COST-BENEFIT ANALYSIS AND PROJECT DESIGN

This material has been produced by the
Training and Development Division,
United States Agency for International Development and
PASITAM, the Program of Advanced Studies in Institution Building
and Technical Assistance Methodology of
MUCIA, the Midwest Universities Consortium for International Activities

REVISED AUGUST 1981

WORKBOOK

Quantitative Procedures and Applications

COST-BENEFIT ANALYSIS AND PROJECT DESIGN

Prepared by John D. Donahue
Assisted by Jurgen Simon

This material has been produced by the
Training and Development Division,
United States Agency for International Development and
PASITAM, the Program of Advanced Studies in Institution Building
and Technical Assistance Methodology of
MUCIA, the Midwest Universities Consortium for International Activities

PASITAM 400 E. Seventh Street, Indiana University, Bloomington Indiana 47405 U.S.A.

Contractors undertaking projects under government sponsorship are encouraged to express freely their professional judgment in the conduct of the project. Points of view or opinions stated do not, therefore, necessarily represent official AID position or policy.

Printed in the United States of America
1980

INTRODUCTION

Cost-benefit analysis, as a tool for project design and appraisal, brings together economic *principles*, empirical *data*, and quantitative *techniques* to produce organized, clear, and easily-understood estimates of a project's value. The videotape portion of this module, and the readings, covered the economic (and other) principles behind cost-benefit analysis. The data are specific to each project: finding information--the hardest part--is up to you (or the analysts working with you). This workbook deals with the third part--the quantitative procedures, the mechanics of cost-benefit analysis. They are fairly simple, and this workbook will pose few serious challenges, even if you are not accustomed to doing calculations (although it will probably go faster if you are.)

The workbook is an integral part of the module. Understanding the mechanics helps to put cost-benefit analysis into perspective, and will improve your ability to know when to have an analysis done, and judge just what you have when it's finished.

Contents This workbook has two main parts. Together, they form a sequence that first introduces you to the mechanics, and then lets you develop a little expertise in applying them. When you have finished you will know how to construct a cash flow projection, how to discount future costs and benefits, and how to compute a project's net present worth, benefit-cost ratio, and internal rate of return. And you will have a solid understanding of what these things mean.

The first part introduces the *procedures* needed to do a cost-benefit analysis. Each procedure is covered in a short section that gives the *purpose*, the *data requirements*, and the *results*. The necessary formulas and abbreviations are explained and illustrated. Special *worksheets* that speed and simplify the procedures are introduced here, and step-by-step *instructions* show how to use the worksheets and formulas to do the mechanics. Then, once each procedure is explained, you get a dry run through it using a simple fictional example--a tractor project in the country of "Temasak."*

---

*The procedures and the Temasak tractor case are based on materials in PASITAM's "toolbook" by Peter Delp and his associates, *Systems Tools for Project Planning* (PASITAM, 1977)

The second part is a *case study* that lets you use what you've learned and do a cost-benefit analysis of an irrigation project. Technical, financial, and economic descriptions give you all the data you'll need (and here, *not* in the mechanics, is where this workbook exercise is easier than project analysis in the real world.) This material is drawn from an actual project, and you deal with the same issues as did the team of specialists involved in it.

Finally, an *appendix* gives the discount factors and annuity factors you will need to complete the case study analysis, and answers for checking your work.

To do the exercises in this workbook, you will need:

--a four-function calculator
--pens and pencils
--extra paper for calculations

You can work alone, or in small groups. You should do the work in two sessions; they will probably take one to two hours for the procedures, and two to four hours for the case exercise. Do not hesitate to go back to the first section to firm up your grasp of a procedure if you get stuck in the case exercise. The results of each stage of the exercise are provided; you should check the answers as you go along, so a minor mistake in arithmetic or transferring data won't cause problems as you go through the case study.

A Cautionary Note

This workbook shows how the basic technical aspects of cost-benefit analysis work. It does not present a special methodology. Nor does it deal with the *non-technical* dimensions of cost-benefit analysis--and these aspects, as the other materials have emphasized, are the most challenging. The purpose here is to make the mechanics completely clear to you, so that you can concentrate on the more important dimensions of economic choices.

The videotape program and the reader have shown how important--and how inescapable--*judgments* and *predictions* are for any cost-benefit analysis. This fundamental fact should be kept in mind--it puts the mechanics in perspective.

Go to it!

PART 1
PROCEDURES

This part of the workbook introduces and illustrates the five main procedures involved in cost-benefit analysis:

--estimating the "cash flow" of a project
--discounting future costs and benefits
--calculating the net present worth of a project
--calculating the project's benefit-cost ratio
--estimating the project's internal rate of return

Each procedure is presented in a section that follows this structure:

1. The procedure is introduced and its *purpose* is explained.
2. Important *definitions, special terms,* and *abbreviations* associated with the procedure are listed and explained.
3. The *assumptions* involved in using the procedure are briefly covered.
4. The *data requirements* are listed, and the *results* of doing the procedure are described.
5. A step-by-step set of *instructions* shows *how to do* the procedure.
6. An *example* illustrates how the procedure works, and introduces the appropriate *worksheet* that makes it simpler to do.

1. ESTIMATING A PROJECT'S CASH FLOW

PURPOSE

Cash flow (CF) projections:

Provide an overall, organized picture of the costs and benefits a project is expected to cause over its estimated lifetime.

Highlight *negative* cash flow years that might affect the project's financial viability.

Provide the basis for calculating the net present worth, benefit-cost ratio, and internal rate of return.

TERMS AND DEFINITIONS

Incremental costs and benefits are the *changes* caused by the project--the difference between the situation anticipated *without* the project and what is expected *with* the project. Incremental values are computed by subtracting the *without project* costs and benefits from the *with project* costs and benefits.

The *annual cash flow* is the *net* incremental benefit for each year of the project--the difference between incremental benefits and incremental costs.

Do not be mislead by the term "cash" flow. Only in financial cost-benefit analysis are costs and benefits limited to cash figures. As the videotape program and reader have shown, economic analysis often includes inputs and outputs whose worth is measured *indirectly* or through *shadow prices* that correct cash values. The label "cash flow" is an accounting term held over in economic cost-benefit analysis.

REQUIREMENTS

Constructing the cash flow requires estimates of the costs and benefits expected to occur each year in two different scenarios: *without* the project and *with* the project. (Note that "with" and "without" are not necessarily the same as "before" and "after.")

RESULTS

A completed cash flow table gives an organized pattern of costs and benefits that *can* be used directly for evaluating choices. For example, if a cash flow in some year is negative, the project may have to be redesigned, or credit may have to be arranged. But more importantly, the cash flow projection establishes a basis for discounted measures of economic soundness--the benefit-cost ratio, net present worth, and internal rate of return.

ASSUMPTIONS

Constructing a truly complete cash flow projection requires that *all* the project's costs and benefits be identified, quantified, and expressed in comparable monetary units. If any are omitted, the cash flow is inconclusive. Every cash flow projection is incomplete in some ways. The goal

is to make it as complete as is practical and necessary for the specific analysis--and then to be aware of its limitations.

DOING THE PROCEDURE

1. *Identify, define, list**

   1.1 Specify the situation the project is to change. Specify the project's aims--the change desired. Identify the changes that are to be taken as costs and those to be taken as benefits.

   1.2 List the costs to be affected by the project. These may include changes in the amounts or prices of goods, raw materials, labor, and management. The "without project" costs must be estimated as carefully as the "with project" costs if the *change* in costs is to be accurately measured.

   1.3 List the categories of benefits that will be affected by the project. These can include increased production efficiency, higher yields, higher quality or prices, time saved, and so on. Again, the key is to contrast "with project" and "without project" estimates.

   1.4 If the cost-benefit analysis is to be economic (rather than just financial) it may be necessary to use shadow prices, or to find ways to indirectly value some costs and benefits. The method of shadow pricing or indirect valuation should be chosen at this point.

   1.5 If the overall cost-benefit analysis involves *weighting* some costs or benefits to reflect special social concerns, the weights can be established here.

2. *Bound the project analysis in time*

   2.1 Estimate the effective life of any major capital equipment.

   2.2 Estimate the *first* year and the *last* year in which the project will yield benefits.

   2.3 Based on these estimates, choose a "project life." (The time boundaries on the analysis are often shorter than engineering estimates. If discounting is to be used, costs and benefits occurring far in the future--more than 50 years, say--will carry almost no weight in the final results.)

---

*You will probably notice that this little section briefly mentions, then passes by, the bulk of the work that will be done for any cost-benefit analysis in the field.

TABLE 1

CASH FLOW

	Years From Project Start			
	Year 1		Years 2 through 10	
Without Project				
Gross Benefits		160		160
Gross Costs		100		100
Net Benefits		60		60
With Project				
Gross Benefits		360		360
Cost Components				
Tractor purchase	500		0	
Operation and maintenance	50		50	
Production costs	130		130	
Gross Costs		680		180
Net Benefits		-320		180
Changes Due To Project				
Incremental Benefits	200		200	
Incremental Costs	580		80	
CASH FLOW	-380		120	

3. *Estimate gross annual costs and benefits* (See Table 1)

   3.1 Estimate the costs and benefits which would occur *without* the project. Enter the estimates into the cash flow table.

   3.2 Estimate the costs and benefits expected to occur *with* the project, and enter *these* estimates in the table.

4. *Compute incremental costs and benefits*

   4.1 For each year, *subtract* the "without project" gross benefits from the "with project" gross benefits. The remainder is the *incremental benefits*: Enter this value in the table.

   4.2 For each year, subtract the "without project" gross costs from the "with project" gross costs. The remainder is the *incremental costs*: Enter this value in the table.

5. *Compute the annual cash flows*

   5.1 *Subtract* the incremental costs from the incremental benefits for each year. The remainder, the *net incremental benefit*, is the annual "cash flow."

EXAMPLE

In the country of Temasek a small farmer spends Ø 100 per year on land preparation, cultivation, seed, and other production costs. (Ø = Unis, the Temasek national currency.) The annual harvest brings him Ø 160, so his net yearly profit is Ø 60.

The Ministry of Agriculture wants to introduce small walking tractors. Technical analysis suggests that owning a tractor would enable the farmer to cultivate more intensively and increase his annual production by 225%. This would lead to annual benefits of Ø 360, with corresponding production costs of Ø 130. A tractor costs the farmer Ø 500 as the initial investment, and Ø 50 each year for operation and maintenance. The estimated life of the tractor is ten years, with no salvage value.

The Ministry of Agriculture field staff prepared a financial cash flow table taking the farmer's point of view. The field staff's financial analyst noted that in the first year the farmer would face a negative cash flow of Ø 380. Therefore, most farmers would need financial assistance to purchase tractors. But for each of the next nine years, every participating farmer would realize an annual estimated cash flow *with* the project Ø 120 greater than *without* it. This suggested the financial feasibility of promoting tractors in Temasek, if investment credit is provided to cover the first-year capital cost.

2. DISCOUNTING

The second procedure takes account of the effects of *time* on relative values. Here is a detailed description of the terms and techniques of discounting.

PURPOSE

Discounting future costs and benefits is a systematic procedure for dealing with the *greater perceived value* of costs and benefits *close to the present* relative to costs and benefits further in the future.

Discounting introduces *time preference* into project appraisal. The "time value" of resources can be a significant consideration when comparing two competing projects each of which would tie up limited resources, or two projects with dissimilar time patterns of costs and benefits.

The basic aim is to determine the equivalent *present worth* of costs and benefits expected at different times, to establish a common, uniform basis for comparing them.

TERMS AND DEFINITIONS

Present worth (PW) is the value *today* of an expected *future* cost or benefit.

The *discount rate* (DR) is a percentage that reflects the *declining value* of costs and benefits as they become more *distant in time*; the discount rate equates future and present worths.

A *discount factor* (DF) is a decimal fraction between zero and one. Discount factors are computed with an equation that brings together the discount rate and the number of years from the present the payment occurs. Future costs and benefits are multiplied by the discount factor to determine their present worth.

An *annuity* is a series of identical annual payments (costs, benefits, or cash flows).

An *annuity factor* (AF) is a "composite" discount factor. It is a shortcut for discounting an annuity.

An *adjusted annuity factor* (AAF) is used to calculate the present worth of a *delayed annuity*--a uniform series that begins a year or more from the present.

NOTATION

1. DF (r/n) = the discount factor for a cost or benefit occurring at year *n* at a discount rate of *r*%.

2. AF (r/n) = the annuity factor used to discount a uniform series of payments (cost, benefit, or cash flow) running from year 1 to year *n* at a discount rate of *r*%.

3. AAF (r/m to n) = the adjusted annuity factor used to discount an annuity running from year *m* (always some year *after* year 1) to year *n* at a discount rate of *r*%.

REQUIREMENTS

Computing present worths requires:

1. Setting an appropriate discount rate.

2. Tabulating costs and benefits for each year--that is, making a cash flow projection.

3. Using a set of discount tables to find discount, annuity, and adjusted annuity factors.

RESULTS

Discounting gives the *present worth* of future values. Discounted costs, benefits, and cash flows are the building blocks for computing the net present worth, the benefit-cost ratio, and the internal rate of return of a project.

ASSUMPTIONS

Discounting a cash flow assumes you have good cash flow projections to begin with--bad estimates never get better by being discounted.

Finding an appropriate discount rate is the main problem. It can be based on one or all of several concerns covered in the reader. It is up to the analyst to find a discount rate that usefully and validly approximates the declining value of costs and benefits over time.

DOING THE PROCEDURE

A. To discount a *single* future payment (cost, benefit, or cash flow):

1. Specify a discount rate.

2. Find the discount factor in discount tables.*

3. Multiply the payment by the discount factor to get the present worth.

Example:

Here is how to compute the present worth of a $200 payment five years from now at several different discount rates: 10%, 15%, and 20%.

---

*Discount tables are lists of solutions to the discount factor equation for every value of *r* and *n*. The equation is: $DF(r/n) = 1/1 + (r/100)^n$. Selected discount tables are printed on pages 61 and 62.

To find DF (10%/5) (that is, the discount factor at the rate of 10% for a payment made in year 5), look in the discount tables (on pages 61-62 in this workbook) under 10%. Go down the column of discount factors, and find the decimal fraction for year 5--.621. At 10%, the present worth of a $200 payment in five years is: PW = $200 x .621 = $124.

At 15%: DF(15%/5) = .497 so PW = $200 x .497 = $99.

And at 20%: DF(20%/5) = .402 so PW = $200 x .402 = $80.

(Cash flow estimates are seldom so precise that it makes sense to worry about great exactness in discounting. Most of the time--and in the case exercise--rounding discount factors to two decimal places is precise enough.)

B. To discount a *non-uniform series* of future payments:

1. Specify the discount rate.

2. List the payment occurring in each year.

3. Look up the discount factor for each year.

4. Compute the present worth of each annual payment.

Example:

An investment opportunity requires spending $150 in the first year and $75 the second year. It will pay out $300 in the third year. Ignoring the time factor, the investment is profitable--paying $225 yields $300, for a profit of $75.

If costs and benefits are discounted at a rate of 20%, does the investment still make sense?

Year 1: pay in $150 DF(20%/1) = .833 so PW = $125 x .833 = $125.
Year 2: pay in $75 DF(20%/2) = .694 so PW = $75 x .694 = $52.
Year 3: receive $300 DF(20%/3) = .579 so PW = $300 x .579 = $174

Discounting at 20% the total costs are $177 and total return is $174--*with* discounting, what previously looked profitable now shows up as a net loss of $3.

C. To discount an *annuity*:

1. Determine the discount rate.

2. Look up the annuity factor in the discount tables.*

---

*The annuity factor is *composite* discount factor. Looking at the tables of annuity factors next to tables of discount factors, you can see that the AF is a running total of DF's--AF(15%/3) = DF(15%/1) + DF(15%/2) + DF(15%/3). Annuity factors are provided on pages 63 and 64.

3. Multiply the annual payment in the series by the annuity factor to get the total present worth of the series of future payments.

Example:

Suppose an investment will yield a uniform annual cash flow of $40 beginning in year 1 and ending in year 5. To find the annuity's present worth at a discount rate of 15%:

Look up the annuity factor:
AF (15%/5) = 3.352
Multiply the *annual* payment by the AF:
PW = $40 x 3.352 = $134

D. To discount a *delayed* annuity:*
(The exercise in Part II uses adjusted annuity factors in nearly every step.)

1. Determine the discount rate.

2. Look up the two annuity factors:

   AF (r/m-1)
   AF (r/n)
   where m = first year of the delayed annuity
   n = last year of the delayed annuity

3. Calculate the adjusted annuity factor for a uniform series from year m to year n: AAF (r/m to n) = AF (r/n) - AF (r/m-1).

4. Multiply the uniform *annual* payment by the AAF to determine the present worth of the delayed annuity.

Example:

A project with a life of 15 years yields no benefits until year 6. From then through year 15 it will yield $100 per year. If the discount rate is 10%, the present worth of the benefits can be determined:

AF (10%/6-1) = 3.791
AF (10%/15) = 7.606
AAF = 7.606 - 3.791 = 3.815

The present worth of a delayed annuity of $100 from year 6 to year 15 is $381.50.

PW = $100 x 3.815 = $381.5

---

*Annuity factors include the years from 1 to n; if the uniform series starts after year 1, the *adjusted* annuity factor described here must be used.

3. ESTIMATING A PROJECT'S NET PRESENT WORTH

The net present worth (NPW) is one of three summary measures for expressing a project's cost-benefit relationships. It is a very simple procedure--summing up the products of discounting

PURPOSE

Estimating a project's net present worth:

Provides a *criterion of acceptability* for a single project. If the NPW is greater than zero, then the project makes sense--assuming cash flow projections and the discount rate are valid.

Sets up a system for *ranking* mutually-exclusive projects or project designs.

Gives an *intermediate measure* necessary in calculating a project's internal rate of return.

TERMS AND DEFINITIONS

The net present worth is the same thing as the net present value (NPV); the terms are used interchangeably.

The NPW is an *absolute* measure of a project's value--total discounted benefits minus total discounted costs, expressed in dollars and cents (or other currency units). The benefit-cost ratio and internal rate of return are both *relative* measures of *units* of output expected per *unit* of input.

Mutually-exclusive alternatives are competing projects or project designs of which only one can be implemented. The NPW is the best summary measure for comparing mutually-exclusive alternatives since if only one project can be done, it makes sense to go with the one promising the greatest absolute net benefits. For example, if a team of engineers must choose between building a big dam or a small, superbly designed dam, the total worth (the NPW) of the big dam would be greater, even though the unit-for-unit efficiency (represented by the benefit-cost ratio or internal rate of return) of the small dam would be better. The NPW takes account of *scale*.

ASSUMPTIONS

The validity of NPW calculations depends on the completeness and reliability of the cash flow projections, and on the appropriateness of the discount rate.

DOING THE PROCEDURE

1. *Estimate* the cash flow for the project, and set up the cash flow table.

2. *Calculate* the cash flow for each year--that is, the net incremental benefits.

3. *Specify* the discount rate.

4. *Look up* discount and annuity factors for each year. (Use annuity factors and adjusted annuity factors whenever you can; it speeds the procedure.)

5. Using the factors and the cash flow estimates, *compute* the present worth of *each* annual cash flow. Usually, some years will have negative and some positive cash flows.

6. *Add up* all the discounted cash flows--the sum is the NPW.

EXAMPLE

The cash flow for a small farmer tractor purchase project was constructed on Table 1, page 6. Suppose Temasek's Office of Project Analysis has specified 15% as the discount rate to be used for rural development projects. Table 2 is a NPW worksheet--like Table 1, it takes advantage of the uniform series (annuity) in years 2 through 10 to make for a shorter worksheet and to allow using adjusted annuity factors instead of discounting year by year.

TABLE 2

NET PRESENT WORTH

Discount Rate 15%

YEAR			INCREMENTAL BENEFITS	INCREMENTAL COSTS	ANNUAL CASH FLOW	PRESENT WORTH OF CASH FLOW
1	discount factor	.87	200	580	-380	-330.6
2 through 10	adjusted annuity factor	4.15	200	80	120	498
				NET PRESENT WORTH		167.4

TABLE 3

CASH FLOW

	Years From Project Start			
	Year 1		Years 2 through 10	
Without Project				
Gross Benefits		160		160
Gross Costs		100		100
Net Benefits		60		60
With Project				
Gross Benefits		240		240
Cost Components				
Production costs	120		120	
Tractor rental	40		40	
Gross Costs		160		160
Net Benefits		80		80
Changes Due To Project				
Incremental Benefits	80		80	
Incremental Costs	60		60	
CASH FLOW	20		20	

The net present worth of purchasing a tractor is ₱ 167.4--certainly greater than zero, and so the tractor project ought to be accepted--*if* it is the only option. But the point of cost-benefit analysis is *comparing and choosing* among alternatives. The tractor-purchase option is sound in its own right, but maybe some mutually-exclusive alternative would be better.

Suppose the Ministry of Agriculture has developed an alternative design, where instead of buying tractors, farmers rent them. Similar tractors can be rented for ₱ 40 a year--a lower cost than buying them, even when spread over several years. But the yields are also lower than what is expected from owning a tractor.

The projected cash flow for a farmer going with the rental option has been entered into Table 3.

Table 4 takes this cash-flow data and, just as for the purchase option, computes the net present worth.

TABLE 4

NET PRESENT WORTH

Discount Rate 15%

YEAR		INCREMENTAL BENEFITS	INCREMENTAL COSTS	ANNUAL CASH FLOW	PRESENT WORTH OF CASH FLOW
1	discount factor .87	80	60	20	17.4
2 through 10	adjusted annuity factor 4.15	80	60	20	83
			NET PRESENT WORTH		100.4

So NPW calculations suggest that a tractor-rental project would be economically viable, too. The NPW is greater than zero, indicating that the project is economically efficient--assuming, always, that projections and the discount rate are valid. But the tractor purchase option still has the larger NPW, reflecting the greater *absolute* economic value of this option. If the decision is to turn on the NPW criterion, and the projects are mutually exclusive, the purchase project should still be chosen. (Although if resources allow it might make sense to implement *both* projects in different areas, since both are economically sound.)

4. ESTIMATING A PROJECT'S BENEFIT-COST RATIO

The benefit-cost ratio is the second common measure of a project's worth; it is similar to the NPW in the way it is calculated, but somewhat different in emphasis.

PURPOSE

The benefit-cost ratio (BCR) compares the value of *units* of input per *unit* of output. It can be used:

To determine the acceptability of a *single* project.

To *rank-order* several possible projects that are *not* necessarily mutually exclusive.

To evaluate and rank alternative *project designs* to specify the most efficient.

TERMS AND DEFINITIONS

The benefit-cost ratio is a *relative* measure of a project's input-output characteristics, unlike the net present worth which is an absolute measure of profit.

Ranking alternatives by benefit-cost ratios gives a picture of the relative *efficiency* of resource use.

ASSUMPTIONS

As for the NPW, the reliability of the benefit-cost ratio depends on the quality of cash flow estimates and the discount rate that make it up.

DOING THE PROCEDURE (See Table 5)

1. *Estimate* the project's cash flow and set up a cash flow table.

2. *Specify* the discount rate.

3. *Look up* discount and annuity factors for each year. When possible, use annuity and adjusted annuity factors.

4. *Discount* the incremental *benefits* for each year.

5. *Add up* the discounted annual incremental benefits; this is the present worth of the incremental benefits.

6. *Discount* the incremental *costs* for each year.

7. *Add up* the discounted annual incremental costs; this is the present worth of the incremental costs.

8. *Divide* the present worth of the incremental benefits by the present worth of the incremental costs to get the benefit-cost ratio.

EXAMPLE

In Table 1 (page 6) the cash flow of a project to purchase a small tractor was estimated and organized. Table 5 is a benefit-cost ratio worksheet--the data from Table 1 are entered in and discounted at 15%.

TABLE 5

BENEFIT-COST RATIO

Discount Rate 15%

YEAR		INCREMENTAL COSTS	PRESENT WORTH OF INCREMENTAL COSTS	INCREMENTAL BENEFITS	PRESENT WORTH OF INCREMENTAL BENEFITS
1	discount factor .87	580	504.6	200	174
2 through 10	adjusted annuity factor 4.15	80	332	200	830
Total			836.6		1004

$$\text{BENEFIT/COST RATIO} = \frac{\text{Present Worth of Incremental Benefits}}{\text{Present Worth of Incremental Costs}}$$

$$= \frac{1004}{836.6}$$

$$= 1.2$$

The benefit-cost ratio is 1.2 This simply suggests that the project is financially sound--that the expected benefits over the life of the project exceed the expected costs, even when time is accounted for. Given the assumptions, this analysis indicates that a "unit" of resources spent on a tractor will generate 1.2 "units" of value.

Now, suppose farmers have another option--forming a tractor cooperative. The members of the coop would pool their resources to buy a large tractor. Since the coop members would share the tractor, each of them would enjoy a lower increase in yields than he would get if he owned a tractor, but his costs would be lower as well. How does the benefit-cost ratio of this option compare with tractor purchase?

Table 6 sets up the cash flow for the coop project alternative.

TABLE 6

CASH FLOW

	Years From Project Start			
	Year 1		Years 2 through 10	
Without Project				
Gross Benefits		160		160
Gross Costs		100		100
Net Benefits		60		60
With Project				
Gross Benefits		270		270
Cost Components				
Initial charter fee	150		0	
Annual membership fee	25		25	
Production costs	120		120	
Gross Costs		295		145
Net Benefits		- 25		125
Changes Due To Project				
Incremental Benefits	110		110	
Incremental Costs	195		45	
CASH FLOW	- 85		65	

Table 7 arranges the cash flow information f r the tractor coop, applies a 15% discount rate, and computes the benefit-cost ratio.

TABLE 7

BENEFIT-COST RATIO

Discount Rate 15%

YEAR		INCREMENTAL COSTS	PRESENT WORTH OF INCREMENTAL COSTS	INCREMENTAL BENEFITS	PRESENT WORTH OF INCREMENTAL BENEFITS
1	discount factor .87	195	169.65	110	95.7
2 through 10	adjusted annuity factor 4.15	45	186.75	110	456.5
Total			356.4		552.2

$$\text{BENEFIT/COST RATIO} = \frac{\text{Present Worth of Incremental Benefits}}{\text{Present Worth of Incremental Costs}}$$

$$= \frac{552.2}{356.4}$$

$$= 1.5$$

The ratio of 1.5 for the coop alternative is considerably higher than the purchase option's ratio, 1.2. This suggests that forming a tractor coop is a more *efficient* use of resources than buying tractors.

5. ESTIMATING A PROJECT'S INTERNAL RATE OF RETURN

So far, two summary measures have been presented for showing the discounted cost-benefit characteristics of a project. The third summary measure is the internal rate of return--popular because it can be calculated without specifying a discount rate in advance, and because it is similar to the familiar idea of the return on an investment.

PURPOSE

The internal rate of return (IRR) measures the *yield* of a project. Estimating the internal rate of return can:

Provide a basis for *evaluating* a single project or project design; estimated IRR's are tested against a *stipulated threshold* of acceptability.

Be used as a criterion for rank-ordering several alternative projects or project designs. Like the benefit-cost ratio, the IRR is a measure of efficiency.

TERMS AND DEFINITIONS

The IRR, like the benefit-cost ratio and unlike the NPW, is a *relative* measure of financial or economic soundness, closely analogous to the "yield" of a conventional financial investment.

In financial cost-benefit analysis the IRR is sometimes called the internal *financial* return. In other cases, it may be called the *economic* or *social* rate of return. The difference is in the point of view the analysis takes, and the definition of the costs and benefits that go into the cash flow projection--not in the form of the IRR calculations.

The IRR is formally defined as the *discount rate at which the NPW is zero*. When the IRR is the criterion for economic soundness, no discount rate is selected before the analysis, but a "cut-off" is set--a rate below which a project is not financially or economically acceptable.

ASSUMPTIONS

As always, the soundness of any summary measure depends on the quality of the data it summarizes.

The IRR has advantages--most importantly, it avoids the problem of finding an appropriate discount rate, one of the weakest links in most cost-benefit analyses (although in some ways it just *postpones* the issue, since a cut-off point must still be set). One disadvantage of the IRR, compared to the NPW or BCR, is that it can *only be calculated when at least one annual cash flow is negative*.

TABLE 8

INTERNAL RATE OF RETURN
TRACTOR PURCHASE

I. Calculate Net Present Worth with different Discount Rates until you have a POSITIVE and a NEGATIVE NPW.

CASH FLOW YEAR 1 -380 CASH FLOW YEARS 2-10 120

Trial Discount Rate	Discount Factor Year 1	Present Worth Year 1	Adjusted Annuity Factor Years 2-10	Present Worth Years 2-10	Net Present Worth at Trial Discount Rate
15%	.87	-330.6	4.15	498	167.4
25%	.8	-304	2.77	332.4	28.4
30%	.77	-292.6	2.32	278.4	- 14.2

II. TRANSFER FROM TABLE

Low TDR 25

High TDR 30

NPW at Low TDR 28.4

NPW at High TDR -14.2

III. CALCULATE

High TDR - Low TDR 5

NPW at Low TDR + Absolute Value of NPW at High TDR 42.6

IV. INTERPOLATE

$$\text{IRR} = \text{Low TDR} + \left[\text{High TDR} - \text{Low TDR} \times \frac{\text{NPW at Low TDR}}{\text{NPW at Low TDR} + \text{Absolute Value of NPW at High TDR}}\right]$$

$$\text{IRR} = 25 + \left[5 \times \frac{28.4}{42.6}\right]$$

$$\text{IRR} = 25 + \left[5 \times .67\right]$$

$$\text{IRR} = 25 + 3.35$$

$$\text{IRR} = 28.35$$

DOING THE PROCEDURE (See Table 8)

Finding the IRR is a two-step procedure. First, the NPW is calculated using several different discount rates. Once a NPW of zero is "bracketed"--that is, falls between two trial discount rates--a technique called *interpolation* is used to specify where the actual IRR lies.

I. *Bracket the IRR* (find discount rates above and below an NPW of zero):

1. *Estimate* the project's cash flow.

2. *Select* a trial discount rate (TDR).*

3. *Calculate* the NPW of the cash flow at the TDR. Use annuity factors and adjusted annuity factors to discount whenever you can.

4. *Evaluate* the NPW and select a second TDR. If the NPW at the first TDR is large and negative--the TDR is higher than the IRR; so choose a smaller TDR. If the NPW at the first TDR is large and positive, the TDR is lower than the IRR; then choose a larger TDR. (It is usually simplest to use TDR's that are multiples of 5 or 10.)

5. *Compute* the NPW using the second TDR.

6. *Evaluate* the NPW and select another TDR. Repeat the procedure until the discount rate which forces the NPW to *zero* is "bracketed"--for example, you have a small negative NPW at TDR = 30% and a small positive NPW at TDR = 25%. ("Small" is relative here, of course.)

---

*The closer this first trial discount rate is to the actual IRR, the fewer calculations there will be. Examining the cash flow can make the first guess better--if the first annual cash flows are large and negative and the positive cash flows are small and delayed, the IRR is probably low--start with 5% or 10%. If positive cash flows start soon and are large relative to negative cash flows, try a high TDR.

II. *Interpolate*

Once you have bracketed the IRR, this procedure specifies just where the IRR is between the two TDR's.

1. *Subtract* the low TDR from the high TDR.

2. *Add* the NPW at the low TDR plus the *absolute value* of the NPW at the high TDR. (The NPW at the high TDR will be negative; using the "absolute value" means *ignoring this* and *treating it as positive*.)

3. *Plug* the appropriate values into this equation and solve it:

$$\text{IRR} = \text{Low TDR} + \left[\begin{array}{l}\text{High TDR} \\ \text{-Low TDR} \times \dfrac{\text{NPW at Low TDR}}{\begin{array}{l}\text{NPW at Low TDR} \\ \text{+ absolute value} \\ \text{of NPW at High TDR}\end{array}}\end{array}\right]$$

Suppose, for example, the IRR has been bracketed by a low TDR of 5% which gives a NPW of $100, and high TDR of 10% which gives a NPW of -$50. Interpolation goes like this:

Low TDR = 5

High TDR
-Low TDR = 5

NPW at Low TDR = 100

NPW at Low TDR
+ absolute value
of NPW at High TDR = 150

$$\text{IRR} = 5 + \left[5 \times \frac{100}{150}\right]$$

$$\text{IRR} = 5 + \left[5 \times .67\right]$$

$$\text{IRR} = 5 + 3.35$$

$$\text{IRR} = 8.35$$

EXAMPLE

Three options have been presented for Temasekian farmers who want to use tractors: buying small tractors, renting them, or forming a coop to buy a larger tractor and dividing its use among themselves.

Cash flows have already been constructed for each option (see pages 6, 14, and 20). Since all three cash flows are uniform after the first year, it is easy to calculate NPW's. Tables 8, 9, and 10 (pages 23, 26, and 27) go through both parts of the IRR procedure.

TABLE 9

INTERNAL RATE OF RETURN
TRACTOR RENTAL

I. Calculate Net Present Worth with different Discount Rates until you have a POSITIVE and a NEGATIVE NPW.

CASH FLOW YEAR 1 20 CASH FLOW YEARS 2-10 20

Trial Discount Rate	Discount Factor Year 1	Present Worth Year 1	Adjusted Annuity Factor Years 2-10	Present Worth Years 2-10	Net Present Worth at Trial Discount Rate
15	.87	17.4	4.15	83	100.4
25	.8	16	2.77	55.4	71.4
30	.77	15.4	2.32	46.4	61.8
35	.74	14.8	1.97	39.4	54.2
40	.71	14.2	1.7	34	48.2
50	.67	13.4	1.30	26	39.4
75	.57	11.4	.76	15.2	26.6
99	.50	10	.51	10.2	20.2

The IRR cannot be calculated when all cash flows are positive, since--no matter how high the TDR--there is no way to get a negative NPW.

TABLE 10

INTERNAL RATE OF RETURN
TRACTOR CO-OP

I. Calculate Net Present Worth with different Discount Rates until you have a POSITIVE and a NEGATIVE NPW.

CASH FLOW YEAR 1 -85 CASH FLOW YEARS 2-10 65

Trial Discount Rate	Discount Factor Year 1	Present Worth Year 1	Adjusted Annuity Factor Years 2-10	Present Worth Years 2-10	Net Present Worth at Trial Discount Rate
15	.87	-73.95	4.15	269.75	195.8
25	.80	-68	2.77	180.05	112.05
50	.67	-56.95	1.30	84.5	27.55
75	.57	-48.45	.76	49.4	.95
80	.56	-47.6	.69	44.85	- 2.75

II. TRANSFER FROM TABLE

Low TDR 75

High TDR 80

NPW at Low TDR .95

NPW at High TDR - 2.75

III. CALCULATE

High TDR - Low TDR 5

NPW at Low TDR + Absolute Value of NPW at High TDR 3.7

IV. INTERPOLATE

$$\text{IRR} = \text{Low TDR} + \left[\text{High TDR} - \text{Low TDR} \times \frac{\text{NPW at Low TDR}}{\text{NPW at Low TDR} + \text{Absolute Value of NPW at High TDR}}\right]$$

$$\text{IRR} = 75 + \left[5 \times \frac{.95}{3.7}\right]$$

$$\text{IRR} = 75 + \left[5 \times .26\right]$$

$$\text{IRR} = 75 + 1.3$$

$$\text{IRR} = 76.3$$

PART 2
A PROBLEM IN PROJECT DESIGN

PROJECT SCENARIO

Bangladesh is not self-sufficient in rice, and new agricultural strategies are being explored. Government policies aim to provide incentives for farmers to increase rice production. These policies include modest price supports for rice, and subsidies on fertilizer, pesticides, and petroleum products used in farming.

Studies indicate that irrigation is the most important constraint on agricultural production. A reliable water supply makes possible a dry-season crop, and increases yields in the wet season by allowing for more flexible planting schedules. The government of Bangladesh and a number of donor agencies are concentrating their efforts on relaxing the irrigation constraint.

You have been called on to conduct a cost-benefit study for a team of officials and technicians designing an irrigation program. The project area consists of five *thanas* (administrative units analogous to counties). There is little irrigation in any of these thanas. All five have similar soil characteristics, ground water supplies, and cropping patterns. Average yields are roughly equal throughout the project area. In other respects there is some diversity.

Two of the thanas have fairly good road networks; the others have few all-weather roads. There are wide differences in land ownership patterns and average income. One thana is designated a serious poverty area. Two are quite prosperous, with most farms much larger than average holdings in Bangladesh. In the other two thanas, tenancy patterns and average incomes are fairly typical for the country.

Rice yields in the project area are low, 800 pounds per acre. The prevailing price of rice is 1 taka per pound--including a government price-support element averaging 8 percent--and the gross income from an acre of unirrigated land is T.800. Out of this farmers

must pay for fertilizer and pesticides, supplied through an extension program at a per-acre cost of T.100* for a one-crop supply.

Wage labor is uncommon in the project area, so the cost of labor is ignored in identifying inputs and outputs for rice production. (The soundness of your cost-benefit analysis will be affected by the validity of ignoring labor costs.)

Irrigated land can yield 2000 pounds of rice per acre. A large part of this increase is from double cropping, so fertilizer and pesticide requirements double. If the irrigation program goes through, these extra chemicals will cost farmers T.200 per acre (100 for farming as usual, 100 for the second crop).

Water management specialists have identified deep tubewells as the most promising irrigation technique, and recommended installing 1000 tubewells in the project area. Engineering studies have identified two alternative well designs. Your task is to assess their respective costs and benefits.

OPTION 1: Wells are drilled by contractors using heavy truck-mounted equipment. Few Bangladeshi firms possess the rigs, so most of the drilling would be contracted out to overseas firms. The drilling rigs require good roads for getting to and from drilling sites. Once drilled, an Option 1 well is fitted with a fiberglass screen and a turbine pump with a high-speed diesel engine. Both screen and pump are imported, though the pumphouses are made domestically.

The diesel engines burn 1000 gallons of fuel in a year's operation. Since the fuel is used for agricultural production, it is available at the subsidized price of T.10 per gallon, or T.10,000 annually per well.

Here is the total investment cost of an Option 1 well:

Imported equipment	T.130,000
Foreign contractors	T. 40,000
Domestic equipment	T. 30,000
Skilled domestic labor	T. 50,000
Unskilled domestic labor	T. 10,000
TOTAL	T.260,000

An Option 1 well can irrigate a command area of 100 acres, so investment costs per acre are T.2,600.

OPTION 2: Wells are somewhat less costly but have smaller capacities. They are drilled by labor-intensive water-jet techniques, or by percussion techniques using a weighted bit, a pulley-fitted

*T. = taka, the Bangladesh currency

tripod, and teams of workers to hoist and release the bit. Tests have shown that jet and percussion wells meet width and straightness requirements. Option 2 wells are fitted mostly with domestic equipment. The brass screens are made in Bangladesh. The centrifugal pumps and low-speed diesel engines are assembled in the country, using a combination of imported and domestic parts.

Fuel requirements are slightly lower for the smaller Option 2 engines--800 gallons per well per year, at a cost of T.8000.

Investment costs for an Option 2 well include:

Imported equipment	T. 50,000
Foreign contractors and consultants	T. 20,000
Domestic equipment	T.100,000
Skilled domestic labor	T. 40,000
Unskilled domestic labor	T. 30,000
TOTAL	T.240,000

The engine and pump are less powerful, and the capacity of the well itself is slightly smaller, so an Option 2 well can irrigate a command area of only 80 acres--per acre investment costs are T.3000.

Project Scheduling

Whichever option is chosen, year 1 of the project will be devoted to forming irrigation groups, selecting sites, and installing the wells. During this first year, rice farming will go on as usual. The wells will be working at the beginning of year 2. From year 2 until year 10 yield increases from irrigation are expected to be realized. Extra fertilizer and pesticide will be required, as well as fuel for the pump engines, from year 2 through year 10.

FINANCIAL FACTSHEET

Your first task is to conduct a financial analysis for this project. Financial analysis tests alternatives to determine which promises the greatest financial incentive to the project's intended clients (and to see whether agency budgets will suffice). It always uses market prices to value costs and benefits.

This financial analysis asks (a) whether tubewell irrigation will be attractive to farmers in the project area and, if so, (b) whether Option 1 or Option 2 offers the better cost-benefit relationship.

Financial Arrangements

Heavy capital costs for drilling and equipment are incurred in the first year of the project. From the second year onward, fuel and extra fertilizer and pesticide for double-cropping are additional costs over the "without project" scenario. Fields will be irrigated beginning in year 2, and farmers can expect increased yields from double-cropping and supplementary wet-season irrigation from year 2 through year 10.

The project design team assumes that few farmers have the cash to pay the full investment cost in the first year, and a credit facility is included in the project. Farmers are to form irrigation groups. Each group will cover the command area of one well (100 acres if Option 1 is chosen, or 80 acres for Option 2). These groups will be required to repay the project agency the cost of their well at 5 percent interest, so this is the discount rate for financial analysis. The farmer must also pay his share of the annual fuel costs for pump engines.

This financial analysis takes the perspective of a farmer as he decides whether to join an irrigation group. The *scale* of the analysis is one acre. Capital, fuel, and agricultural input costs are entered per acre, as are rice yields. (Labor costs, remember, are ignored here.) Note that *in computing capital and fuel costs per acre an Option 1 well irrigates 100 acres and an Option 2 well irrigates 80 acres.*

Use this information, plus

*cost, yield, and price data from the Project Scenario, and
*a calculator.

Compute per-acre cost shares and construct a 10-year cash flow table for each project option.

Using the completed cash flow table

*and the discount tables in Appendix I
*plus a calculator,
*and the procedures in Part 1 for reference

Determine:

(1) The benefit-cost ratio
(2) The net present worth
(3) The internal rate of return for Option 1 and Option 2.

TABLE 11

OPTION 1
FINANCIAL CASH FLOW
COSTS AND BENEFITS PER ACRE

	Years From Project Start			
	Year 1		Years 2 through 10	
Without Project				
Gross Benefits				
Gross Costs				
Net Benefits				
With Project				
Gross Benefits				
Cost Components				
Investment (per-acre well cost)				
Fuel (per-acre share)				
Usual fertilizer and pesticides				
Extra fertilizer and pesticides				
Gross Costs				
Net Benefits				
Changes Due To Project				
Incremental Benefits				
Incremental Costs				
CASH FLOW				

TABLE 12

OPTION 2
FINANCIAL CASH FLOW
COSTS AND BENEFITS PER ACRE

	Years From Project Start			
	Year 1		Years 2 through 10	
Without Project				
Gross Benefits				
Gross Costs				
Net Benefits				
With Project				
Gross Benefits				
Cost Components				
Investment (per-acre well cost)				
Fuel (per-acre share)				
Usual fertilizer and pesticides				
Extra fertilizer and pesticides				
Gross Costs				
Net Benefits				
Changes Due To Project				
Incremental Benefits				
Incremental Costs				
CASH FLOW				

TABLE 13

OPTION 1
BENEFIT-COST RATIO

Discount Rate _____

YEAR		INCREMENTAL COSTS	PRESENT WORTH OF INCREMENTAL COSTS	INCREMENTAL BENEFITS	PRESENT WORTH OF INCREMENTAL BENEFITS
1	discount factor				
2 through 10	adjusted annuity factor				
Total					

$$\text{BENEFIT/COST RATIO} = \frac{\text{Present Worth of Incremental Benefits}}{\text{Present Worth of Incremental Costs}}$$

$$= \frac{\qquad\qquad}{\qquad\qquad}$$

$$=$$

TABLE 14

OPTION 2
BENEFIT-COST RATIO

Discount Rate _____

YEAR		INCREMENTAL COSTS	PRESENT WORTH OF INCREMENTAL COSTS	INCREMENTAL BENEFITS	PRESENT WORTH OF INCREMENTAL BENEFITS
1	discount factor				
2 through 10	adjusted annuity factor				
Total					

$$\text{BENEFIT/COST RATIO} = \frac{\text{Present Worth of Incremental Benefits}}{\text{Present Worth of Incremental Costs}}$$

$$= \frac{\qquad\qquad}{\qquad\qquad}$$

$$=$$

TABLE 15

OPTION 1
NET PRESENT WORTH

Discount Rate _____

YEAR		INCREMENTAL BENEFITS	INCREMENTAL COSTS	ANNUAL CASH FLOW	PRESENT WORTH OF CASH FLOW
1	discount factor				
2 through 10	adjusted annuity factor				
			NET PRESENT WORTH		

TABLE 16

OPTION 2
NET PRESENT WORTH

Discount Rate _____

YEAR		INCREMENTAL BENEFITS	INCREMENTAL COSTS	ANNUAL CASH FLOW	PRESENT WORTH OF CASH FLOW
1	discount factor				
2 through 10	adjusted annuity factor				
			NET PRESENT WORTH		

TABLE 17

OPTION 1
INTERNAL RATE OF RETURN

I. Calculate Net Present Worth with different Discount Rates until you have a POSITIVE and a NEGATIVE NPW.

CASH FLOW YEAR 1 _____ CASH FLOW YEARS 2-10 _____

Trial Discount Rate	Discount Factor Year 1	Present Worth Year 1	Adjusted Annuity Factor Years 2-10	Present Worth Years 2-10	Net Present Worth at Trial Discount Rate

II. TRANSFER FROM TABLE

Low TDR _____

High TDR _____

NPW at Low TDR _____

NPW at High TDR _____

III. CALCULATE

High TDR - Low TDR _____

NPW at Low TDR + Absolute Value of NPW at High TDR _____

IV. INTERPOLATE

$$\text{IRR} = \text{Low TDR} + \left[\text{High TDR} - \text{Low TDR} \times \frac{\text{NPW at Low TDR}}{\text{NPW at Low TDR} + \text{Absolute Value of NPW at High TDR}}\right]$$

IRR = _____ + [_____ x _____]

IRR = _____ + [_____ x _____]

IRR = _____ + _____

IRR = _____

TABLE 18

OPTION 2
INTERNAL RATE OF RETURN

I. Calculate Net Present Worth with different Discount Rates until you have a POSITIVE and a NEGATIVE NPW.

CASH FLOW YEAR 1 _____ CASH FLOW YEARS 2-10 _____

Trial Discount Rate	Discount Factor Year 1	Present Worth Year 1	Adjusted Annuity Factor Years 2-10	Present Worth Years 2-10	Net Present Worth at Trial Discount Rate

II. TRANSFER FROM TABLE

Low TDR _____

High TDR _____

NPW at Low TDR _____

NPW at High TDR _____

III. CALCULATE

High TDR - Low TDR _____

NPW at Low TDR + Absolute Value of NPW at High TDR _____

IV. INTERPOLATE

$$\text{IRR} = \text{Low TDR} + \left[\text{High TDR} - \text{Low TDR} \times \frac{\text{NPW at Low TDR}}{\text{NPW at Low TDR} + \text{Absolute Value of NPW at High TDR}}\right]$$

IRR = _____ + [_____ x _____]

IRR = _____ + [_____ x _____]

IRR = _____ + _____

IRR = _____

ECONOMIC SURVEY AND DATA

Your second task is to conduct an economic analysis of the proposed project.

Financial analysis asked whether tubewell irrigation would be attractive to farmers, and which of two well designs offered greater financial incentives. Individuals face financial choices defined by market prices, so these prices were used in the financial analysis.

Economic analysis can differ in several ways from financial analysis:

1. The *scale* changes; economic analysis usually considers a broader system than a single farm.

2. *Definitions* of costs and benefits can change to account for effects which are *external* to a limited system but which cause significant gains or losses within the larger economic system. (This exercise does not cover any external effects, but it could--an example might be the tendency of tubewell irrigation to lower the water table in a region.)

3. Financial and economic analysis generally use different *discount rates*.

4. Finally, economic analysis often values costs and benefits by means other than market prices. In classical economic theory, market prices are regarded as perfect measures of economic values. But "perfect competition" is never seen in reality. When money prices and economic values diverge seriously, *shadow prices* may be called for. In this example three kinds of serious price distortions affect five of the inputs and outputs of tubewell irrigation.

Foreign Exchange. You are probably familiar with the idea of a currency being "overvalued"--having an official exchange rate that sets its value too high in relation to other currencies. *Overvalued* domestic currency means *undervalued* foreign exchange. *Shadow exchange rates* represent attempts to adjust for foreign exchange distortions. They put a premium on foreign currency (relative to domestic currency) in cost-benefit calculations.

Suppose the official exchange rate is T.16 = $1, but reliable studies indicate the real value of a dollar is more like T.24. Then the shadow pricing factor for foreign exchange is 24/16, or 1.5. Now the costs of imports requiring foreign exchange--understated in the financial analysis--are corrected in this broader economic assessment of the tubewell project.

Unskilled Labor. Market theory has it that wages are mostly determined by a worker's contribution to production--if he is earning $10 for a job, he is presumably producing goods or services worth at least $10. Drawing him *away from* the job would therefore entail a $10 loss of production. In the real world other factors

besides productivity often set wages--social norms about decent wages, the principle that people should be employed whether productively or not, union pressures, and so on. The significance of this for economic analysis is that a wage may not reflect the *real* cost of labor--and most important, the *opportunity cost* of putting people to work on a project instead of whatever they were previously doing. When unemployment is high--if a worker is drawn from doing almost nothing to working on a project--the *opportunity cost* may be close to zero. So even though a wage is paid, the *economic cost* of hiring a worker may be lower than the money wage (the *financial cost*).

Suppose the unskilled workers hired for drilling wells are to be paid T.30 per day. Most of them, in the absence of the project, would be underemployed. Suppose the real cost--the loss of production elsewhere--of putting them to work is only half of the money wage. Then the *shadow wage rate* for these potential workers is T.15 per day.

Subsidies. To its recipients, a subsidy is a financial benefit. To economists it is a distortion. There are arguments for ignoring subsidies in economic cost-benefit analysis--subtracting any subsidy element from financial benefits and adding the full amount of any subsidies to financial costs. In this case three categories of inputs and outputs are subsidized:

Fertilizer and pesticide are provided to farmers at T.100 for a package sufficient for one application on one acre. The actual cost of these chemicals is T.200. The difference--T.100--is a subsidy from the government or "society" to farmers.

Diesel fuel to run the pumps is subsidized. Irrigation groups will be required to pay T.10 per gallon but the government pays T.20. The difference, T.10, is the subsidy on petroleum products for farm use.

The government also supports *rice prices*. Suppose the economic value of a pound of rice can be reliably estimated at T.0.92. If farmers receive T.1/pound, the economic value of rice is 92% of its market price.

Table 19 presents these shadow pricing factors and shadow prices.

TABLE 19

ITEM	UNIT	FINANCIAL PRICE/UNIT	SHADOW PRICE/UNIT	SHADOW PRICING FACTOR
Foreign Exchange	Dollar	16	24	1.5
Unskilled Labor	Man Day	30	15	.5
Fertilizer and Pesticide	Acre/Crop Package	100	200	2
Fuel	Gallon	10	20	2
Rice	Pound	1	.92	.92

SHADOW PRICING

Applying shadow prices is meant to correct for market imperfections and distortions that make financial cost-benefit relationships unreliable guides to economic good sense. The previous section has listed the nature and magnitude of the price distortions involved here. Now, your task is to take this information and use it to adjust the costs and benefits projected for each well design.

Since some cost factors--investment in the wells, and diesel fuel for running them--take place at the level of the irrigation group rather than individual farmers, this is the level for applying shadow prices. So the first step for moving from financial to economic analysis is to expand the scale from "per-acre" to "per-well."

In order to rescale the analysis to cover the command area of one well:

Go to the financial cash flow tables you set up on pages 20 and 21.
Multiply each item to take it to the per-well scale;
Multiply by 100 for Option 1, and by 80 for Option 2.
Enter the new scaled-up values in the relevant places in tables 20 and 21.

So far, nothing has changed except the scale. If you calculated the benefit-cost ratio or the internal rate of return at this point, it would be just the same as in the financial analysis since these are relative, unit-for-unit measures. The net present worth would be different, though--for Option 1, 100 times as large, and 80 times as large for Option 2, since the NPW takes account of scale.

TABLE 20

OPTION 1
FINANCIAL CASH FLOW
COSTS AND BENEFITS PER WELL

	Years From Project Start			
	Year 1		Years 2 through 10	
Without Project				
Gross Benefits				
Gross Costs				
Net Benefits				
With Project				
Gross Benefits				
Cost Components				
Investment (per well)				
Fuel (per well)				
Usual fertilizer and pesticides				
Extra fertilizer and pesticides				
Gross Costs				
Net Benefits				
Changes Due To Project				
Incremental Benefits				
Incremental Costs				
CASH FLOW				

TABLE 21

OPTION 2
FINANCIAL CASH FLOW
COSTS AND BENEFITS PER WELL

	Years From Project Start			
	Year 1		Years 2 through 10	
Without Project				
Gross Benefits				
Gross Costs				
Net Benefits				
With Project				
Gross Benefits				
Cost Components				
Investment (per well)				
Fuel (per well)				
Usual fertilizer and pesticides				
Extra fertilizer and pesticides				
Gross Costs				
Net Benefits				
Changes Due To Project				
Incremental Benefits				
Incremental Costs				
CASH FLOW				

Now that the scale is right for economic analysis, you can apply the shadow pricing factors derived above (pages 41-43) to correct for problems with the market prices of inputs and outputs.

TO DO THIS:
Go back to the shadow pricing table on page 43.

USING
*these shadow pricing factors
*the per-acre cash flow figures you just calculated
*your calculator
*and the shadow pricing worksheets

Multiply each item by the relevant shadow pricing factor, then *Enter* the adjusted values in the economic cash flow tables 24 and 25.

Now you have cash flow estimates that better reflect the economic realities affecting this problem of project design (assuming the logic and data behind the system of shadow pricing are valid). You are almost ready to compute summary measures. But one more point needs to be covered.

The financial analysis was keyed to the financial costs and benefits faced by individual farmers. Farmers received credit for well cooperatives at an interest rate of 5 percent. This was the discount rate used for financial analysis. But this interest rate reflects a substantial subsidy element, since the government heavily subsidizes credit to farmers. To decide whether tubewell irrigation makes economic sense the project designers want a more rigorous indication of economic efficiency. Thus, you will want to use a discount rate that really reflects the opportunity cost of investment resources. For agricultural projects in Bangladesh, the appropriate discount rate is estimated at 10%.

NOW USING
*the economic cash flow tables you just computed
*and applying a 10% discount rate

FILL IN tables 26 and 27 to estimate the net present worth of each option.

THEN USING
*the economic cash flow figures
*and trial discount and adjusted annuity factors from the Appendix

FILL IN tables 28 and 29 to estimate the internal rate of return of each option.

TABLE 22

SHADOW PRICING WORKSHEET
OPTION 1

Transfer: information from scenario for breakdown of well investment costs (pp. 29-30)

: other cost and benefit data from per-well financial cash flow (p. 44)

: shadow pricing factors from table 19

Multiply the financial value by the shadow pricing factor to get the economic value. When no shadow price has been set, use the financial value - shadow pricing factor = 1.

GROSS BENEFITS

Value of Rice Yield	Financial Benefits	Shadow Pricing Factor	Economic Benefits
Without project and Year 1 with project			
Years 2-10 with project			

INVESTMENT COSTS

Component	Financial Cost	Shadow Pricing Factor	Economic Cost
TOTAL			

RECURRENT COSTS

Without Project and Year 1 with Project: Fertilizer and Pesticide	Financial Cost	Shadow Pricing Factor	Economic Cost
Years 2-10 with project: pump operation			
Fertilizer and pesticide			

TABLE 23

SHADOW PRICING WORKSHEET
OPTION 2

Transfer: information from scenario for breakdown of well investment costs (pp. 30-31)

: other cost and benefit data from per-well financial cash flow (p. 45)

: shadow pricing factors from table 19

Multiply the financial value by the shadow pricing factor to get the economic value. When no shadow price has been set, use the financial value - shadow pricing factor = 1.

GROSS BENEFITS

Value of Rice Yield	Financial Benefits	Shadow Pricing Factor	Economic Benefits
Without project and Year 1 with project			
Years 2-10 with project			

INVESTMENT COSTS

Component	Financial Cost	Shadow Pricing Factor	Economic Cost
TOTAL			

RECURRENT COSTS

Without Project and Year 1 with Project: Fertilizer and Pesticide	Financial Cost	Shadow Pricing Factor	Economic Cost
Years 2-10 with project: pump operation			
Fertilizer and pesticide			

TABLE 24

OPTION 1
ECONOMIC CASH FLOW
COSTS AND BENEFITS PER WELL

	Years From Project Start			
	Year 1		Years 2 through 10	
Without Project				
Gross Benefits				
Gross Costs				
Net Benefits				
With Project				
Gross Benefits				
Cost Components				
Investment (per well)				
Fuel (per well)				
Usual fertilizer and pesticides				
Extra fertilizer and pesticides				
Gross Costs				
Net Benefits				
Changes Due To Project				
Incremental Benefits				
Incremental Costs				
CASH FLOW				

TABLE 25

OPTION 2
ECONOMIC CASH FLOW
COSTS AND BENEFITS PER WELL

	Years From Project Start			
	Year 1		Years 2 through 10	
Without Project				
Gross Benefits				
Gross Costs				
Net Benefits				
With Project				
Gross Benefits				
Cost Components				
Investment (per well)				
Fuel (per well)				
Usual fertilizer and pesticides				
Extra fertilizer and pesticides				
Gross Costs				
Net Benefits				
Changes Due To Project				
Incremental Benefits				
Incremental Costs				
CASH FLOW				

TABLE 26

OPTION 1
NET PRESENT WORTH

Discount Rate _____

YEAR			INCREMENTAL BENEFITS	INCREMENTAL COSTS	ANNUAL CASH FLOW	PRESENT WORTH OF CASH FLOW
1	discount factor					
2 through 10	adjusted annuity factor					
				NET PRESENT WORTH		

TABLE 27

OPTION 2
NET PRESENT WORTH

Discount Rate _____

YEAR			INCREMENTAL BENEFITS	INCREMENTAL COSTS	ANNUAL CASH FLOW	PRESENT WORTH OF CASH FLOW
1	discount factor					
2 through 10	adjusted annuity factor					
				NET PRESENT WORTH		

TABLE 28

OPTION 1
INTERNAL RATE OF RETURN

I. Calculate Net Present Worth with different Discount Rates until you have a POSITIVE and a NEGATIVE NPW.

CASH FLOW YEAR 1 _____ CASH FLOW YEARS 2-10 _____

Trial Discount Rate	Discount Factor Year 1	Present Worth Year 1	Adjusted Annuity Factor Years 2-10	Present Worth Years 2-10	Net Present Worth at Trial Discount Rate

II. TRANSFER FROM TABLE

Low TDR _____

High TDR _____

NPW at Low TDR _____

NPW at High TDR _____

III. CALCULATE

High TDR - Low TDR _____

NPW at Low TDR + Absolute Value of NPW at High TDR _____

IV. INTERPOLATE

$$IRR = \text{Low TDR} + \left[(\text{High TDR} - \text{Low TDR}) \times \frac{\text{NPW at Low TDR}}{\text{NPW at Low TDR} + \text{Absolute Value of NPW at High TDR}} \right]$$

IRR = _____ + [_____ x _____]

IRR = _____ + [_____ x _____]

IRR = _____ + _____

IRR = _____

TABLE 29

OPTION 2
INTERNAL RATE OF RETURN

I. Calculate Net Present Worth with different Discount Rates until you have a POSITIVE and a NEGATIVE NPW.

CASH FLOW YEAR 1 _____ CASH FLOW YEARS 2-10 _____

Trial Discount Rate	Discount Factor Year 1	Present Worth Year 1	Adjusted Annuity Factor Years 2-10	Present Worth Years 2-10	Net Present Worth at Trial Discount Rate

II. TRANSFER FROM TABLE

Low TDR _____

High TDR _____

NPW at Low TDR _____

NPW at High TDR _____

III. CALCULATE

High TDR - Low TDR _____

NPW at Low TDR + Absolute Value of NPW at High TDR _____

IV. INTERPOLATE

$$IRR = \text{Low TDR} + \left[\text{High TDR} - \text{Low TDR} \times \frac{\text{NPW at Low TDR}}{\text{NPW at Low TDR} + \text{Absolute Value of NPW at High TDR}}\right]$$

IRR = _____ + [_____ x _____]

IRR = _____ + [_____ x _____]

IRR = _____ + _____

IRR = _____

"SOCIAL" COST-BENEFIT ANALYSIS: USING WEIGHTS IN ECONOMIC ANALYSIS

"Social" cost-benefit analysis tends to be a loosely used term. Sometimes it refers to an economic analysis that takes a "social" perspective on opportunity costs and the value of outputs (as opposed to a financial analysis that deals only with "private" costs and returns). Sometimes "social cost-benefit analysis" stands for something broader, and attempts to account for effects beyond purely economic ones.

One way--though not the only way--to distinguish between social and economic analysis is this: Social cost-benefit analysis incorporate *weights* that reflect social *value judgments* and *redefine* "efficiency". Weights are meant to bring social values to bear systematically on project choices. This final part of the exercise shows one way weights can be derived and applied.

A "Reciprocal-of-Income" Weighting System

Suppose the sponsors of the tubewell project declare a high priority for increasing the incomes of the poor. Analysts can provide a formula that quantifies this concern. First, specify the value judgment precisely like this: "Additional income generated by the project is more valuable as the pre-project income of the recipient is lower." Benefits to poor farmers are more important than to richer ones.

A formula that fits this declaration is this: Divide *1* by a measure based on annual income. This gives the *reciprocal* of income. Use the reciprocal as a weight; this weight is high for low incomes, and low for high incomes.

Computing the Weights

The project area comprises five *thanas*. Most of the land in the first *thana* belongs to large owners, many of whom do not work or live on the land themselves. In the second, land concentration is slightly less, but income is well above the national average. Most holdings in the third *thana* are farmed by small farmers with incomes about average for Bangladesh. In the fourth, incomes are somewhat below the national average, and many farmers in the fifth *thana* suffer serious poverty.

The following table shows the weights for each *thana*.

Table 30
National Average Annual Income = 2000 taka

Thana	*Thana* resident's average annual income	$\frac{\textit{Thana}\text{ average income}}{\text{national average income}}$	Weight = Reciprocal = $\frac{1}{\textit{thana}\text{ av. inc./nat. av. inc.}}$
1	3000 taka	1.5	.67
2	2500 taka	1.25	.8
3	2000 taka	1	1
4	1500 taka	.75	1.33
5	1000 taka	.5	2

Applying the Weights

The reciprocal formula yields a set of weights for the project area that effect the project sponsor's concern for increasing equity. How do these weights affect the choice of technology? As the scenario noted, for technical reasons--truck-mounted drilling rigs need good roads--Option 1 wells can be drilled only in some parts of the project area. The labor-intensive equipment used to drill Type 2 wells can be used throughout the area. Alternative siting plans for each option have been drawn up, revealing the implications of this technical constraint.

For each option, the distribution of the 1000 wells would be:

Distribution of Wells Among Thanas

Thana	Number of Wells Under Option 1	Number of Wells Under Option 2
1	500	200
2	500	200
3	0	200
4	0	200
5	0	200

Since incomes differ among *thanas*, technology choice affects income distribution. One way of entering this into quantitative cost-benefit analysis is by applying the weights to NPW calculations for the whole 1000-well project.

The procedure is to take the NPW per well, multiply it by the number of wells in each *thana*, then multiply the total NPW per *thana* by the *thana's* distributional weight, and sum the weighted NPW for all *thanas:*

Project NPW = per-well NPW x wells per *thana* x *thana* weight.

For Option 1:

Project NPW = per-well NPW x 500 x .67 (*Thana* 1)
+ per-well NPW x 500 x .8 (*Thana* 2)

For Option 2:

Project NPW = per-well NPW x 200 x .67 (*Thana* 1)
+ per-well NPW x 200 x .8 (*Thana* 2)
+ per-well NPW x 200 x 1 (*Thana* 3)
+ per-well NPW x 200 x 1.3 (*Thana* 4)
+ per-well NPW x 200 x 2 (*Thana* 5)

Before filling in the blanks, you must decide *which* NPW to use. There are arguments for using the financial NPW for "social" cost-benefit analysis (it seems silly to disregard subsidies to poor farmers and then apply a distributional weight to benefits they receive). But it is probably best to go with the economic NPW, on the grounds that it accounts for economic realities of value and scarcity and *then* adds this extra criterion of distribution priorities.

TABLE 31

Option 1 *Units* 1000 taka

Economic NPW per well _____

Distribution-weighted
Project NPW = _____ x 500 x .67 = _____

+ _____ x 500 x .8 = _____

= _____

Option 2

Economic NPW per well _____

Distribution-weighted
Project NPW = _____ x 200 x .67 = _____

+ _____ x 200 x .8 = _____

+ _____ x 200 x 1 = _____

+ _____ x 200 x 1.3 = _____

+ _____ x 200 x 2 = _____

= _____

TABLE 32

RESULTS OF ANALYSIS

ALTERNATIVES	*Financial*			*Economic*		*With Distribution Weighting*
	BCR	*NPW taka per acre*	*IRR*	*NPW taka per well*	*IRR*	*NPW 1000 taka per program (1000 wells)*
Capital-Intensive OPTION 1						
Labor-Intensive OPTION 2						

SUMMARY

Go back to each phase of analysis--financial, economic, and "social", or economic with distribution weighting, and fill in the matrix above.

On the basis of your quantitative cost-benefit analysis, what will you tell the project designers who want to know whether to start signing contracts for truck mounted rigs, or to start hiring local workers to drill Option 2 wells?

When you have settled your own position, turn the page for one way of interpreting this cost-benefit analysis and applying it to this problem of project design.

FINAL NOTES

Your *financial* analysis (using market prices that include subsidies, and regulated wage and exchange rates) clearly indicates Option 1 as the better alternative. If the *only* project objective is profit for farmers, Option 1 should be chosen. This financial analysis should indicate to project designers that labor-intensive irrigation techniques will be relatively unattractive to the farmers and contractors who will be involved in the project. If planners are serious about promoting labor-intensive technology--in the economy as a whole as well as for this project--they should look carefully at the signals that prices give to economic actors, and consider adjusting subsidies, taxes, and wage and exchange rate regulations.

In *economic* terms, the results are ambiguous. Net present worth calculations suggest going with Option 1 (though the results are close enough that error in estimation, maybe even in rounding, could tilt it the other way.) This outcome reflects the *absolute* nature of the NPW measure, and the capital-intensive option is simply a bigger project. The internal rate of return criterion points to Option 2--especially if the cut-off point is set at 15%. This means that, *unit for unit*, the labor-intensive alternative makes more sense.

The advice you give on the basis of these results might be this:

The *best* course of action is to go with labor-intensive wells and, since they are more efficient, use the per unit savings--the result of the lower cost of these wells--to expand the project beyond the 1000 wells originally planned. The resources needed to build 1000 Option 1 wells could build a larger number of labor-intensive ones, and then both the IRR and the NPW would be maximized.

If the scale is fixed, for whatever reason, choose Option 1, since 1000 of the capital-intensive wells can irrigate 100,000 acres (instead of 80,000 acres for 1000 Option 2 wells) and the total net benefits are largest with Option 1.

If the reciprocal-of-income weighting system is used, the results are clear--use the labor-intensive option when implementing the project. This reflects the technical constraint on drilling Option 1 wells--they cannot be installed in the poor *thanas* that lack solid roads. If the analysis is to reflect concerns for equity, it is unsurprising that a project design that would bypass the poorest areas is rejected.

Appendices

A. Discounting Tables:
   Discount and Annuity Factors

B. Completed Work Tables

APPENDIX A

DISCOUNTING TABLES

DISCOUNT FACTOR

Year	1%	3%	5%	6%	8%	10%	12%	14%	15%	16%	18%
1	0.990	0.971	0.952	0.943	0.926	0.909	0.893	0.877	0.870	0.862	0.847
2	0.980	0.943	0.907	0.890	0.857	0.826	0.797	0.769	0.756	0.743	0.718
3	0.971	0.915	0.864	0.840	0.794	0.751	0.712	0.675	0.658	0.641	0.609
4	0.961	0.888	0.823	0.792	0.735	0.683	0.636	0.592	0.572	0.552	0.516
5	0.951	0.863	0.784	0.747	0.681	0.621	0.567	0.519	0.497	0.476	0.437
6	0.942	0.837	0.746	0.705	0.630	0.564	0.507	0.456	0.432	0.410	0.370
7	0.933	0.813	0.711	0.665	0.583	0.513	0.452	0.400	0.376	0.354	0.314
8	0.923	0.789	0.677	0.627	0.540	0.467	0.404	0.351	0.327	0.305	0.266
9	0.914	0.766	0.645	0.592	0.500	0.424	0.361	0.308	0.284	0.263	0.225
10	0.905	0.744	0.614	0.558	0.463	0.386	0.322	0.270	0.247	0.227	0.191
11	0.896	0.722	0.585	0.527	0.429	0.350	0.287	0.237	0.215	0.195	0.162
12	0.887	0.701	0.557	0.497	0.397	0.319	0.257	0.208	0.187	0.168	0.137
13	0.879	0.681	0.530	0.469	0.368	0.290	0.229	0.182	0.163	0.145	0.116
14	0.870	0.661	0.505	0.442	0.340	0.263	0.205	0.160	0.141	0.125	0.099
15	0.861	0.642	0.481	0.417	0.315	0.239	0.183	0.140	0.123	0.108	0.084
16	0.853	0.623	0.458	0.394	0.292	0.218	0.163	0.123	0.107	0.093	0.071
17	0.844	0.605	0.436	0.371	0.270	0.198	0.146	0.108	0.093	0.080	0.060
18	0.836	0.587	0.416	0.350	0.250	0.180	0.130	0.095	0.081	0.069	0.051
19	0.828	0.570	0.396	0.331	0.232	0.164	0.116	0.083	0.070	0.060	0.043
20	0.820	0.554	0.377	0.312	0.215	0.149	0.104	0.073	0.061	0.051	0.037

PREVIOUS PAGE BLANK

Year	20%	22%	24%	25%	26%	28%	30%	35%	40%	45%	50%
1	0.833	0.820	0.806	0.800	0.794	0.781	0.769	0.741	0.714	0.690	0.667
2	0.694	0.672	0.650	0.640	0.630	0.610	0.592	0.549	0.510	0.476	0.444
3	0.579	0.551	0.524	0.512	0.500	0.477	0.455	0.406	0.364	0.328	0.296
4	0.482	0.451	0.423	0.410	0.397	0.373	0.350	0.301	0.260	0.226	0.198
5	0.402	0.370	0.341	0.328	0.315	0.291	0.269	0.223	0.186	0.156	0.132
6	0.335	0.303	0.275	0.262	0.250	0.227	0.207	0.165	0.133	0.108	0.088
7	0.279	0.249	0.222	0.210	0.198	0.178	0.159	0.122	0.095	0.074	0.059
8	0.233	0.204	0.179	0.168	0.157	0.139	0.123	0.091	0.068	0.051	0.039
9	0.194	0.167	0.144	0.134	0.125	0.108	0.094	0.067	0.048	0.035	0.026
10	0.162	0.137	0.116	0.107	0.099	0.085	0.073	0.050	0.035	0.024	0.017
11	0.135	0.112	0.094	0.086	0.079	0.066	0.056	0.037	0.025	0.017	0.012
12	0.112	0.092	0.076	0.069	0.062	0.052	0.043	0.027	0.018	0.012	0.008
13	0.093	0.075	0.061	0.055	0.050	0.040	0.033	0.020	0.013	0.008	0.005
14	0.078	0.062	0.049	0.044	0.039	0.032	0.025	0.015	0.009	0.006	0.003
15	0.065	0.051	0.040	0.035	0.031	0.025	0.020	0.011	0.006	0.004	0.002
16	0.054	0.042	0.032	0.028	0.025	0.019	0.015	0.008	0.005	0.003	0.002
17	0.045	0.034	0.026	0.023	0.020	0.015	0.012	0.006	0.003	0.002	0.001
18	0.038	0.028	0.021	0.018	0.016	0.012	0.009	0.005	0.002	0.001	0.001
19	0.031	0.023	0.017	0.014	0.012	0.009	0.007	0.003	0.002	0.001	0.000
20	0.026	0.019	0.014	0.012	0.010	0.007	0.005	0.002	0.001	0.001	0.000

ANNUITY FACTORS

Year	1%	3%	5%	6%	8%	10%	12%	14%	15%	16%	18%
1	0.990	0.971	0.952	0.943	0.926	0.909	0.893	0.877	0.870	0.862	0.847
2	1.970	1.913	1.859	1.833	1.783	1.736	1.690	1.647	1.626	1.605	1.566
3	2.941	2.829	2.723	2.673	2.577	2.487	2.402	2.322	2.283	2.246	2.174
4	3.902	3.717	3.546	3.465	3.312	3.170	3.037	2.914	2.855	2.798	2.690
5	4.853	4.580	4.329	4.212	3.993	3.791	3.605	3.433	3.352	3.274	3.127
6	5.795	5.417	5.076	4.917	4.623	4.355	4.111	3.889	3.784	3.685	3.498
7	6.728	6.230	5.786	5.582	5.206	4.868	4.564	4.288	4.160	4.039	3.812
8	7.652	7.020	6.463	6.210	5.747	5.335	4.968	4.639	4.487	4.344	4.078
9	8.566	7.786	7.108	6.802	6.247	5.759	5.328	4.946	4.772	4.607	4.303
10	9.471	8.530	7.722	7.360	6.710	6.145	5.650	5.216	5.019	4.833	4.494
11	10.368	9.253	8.306	7.887	7.139	6.495	5.938	5.453	5.234	5.029	4.656
12	11.255	9.954	8.863	8.384	7.536	6.814	6.194	5.660	5.421	5.197	4.793
13	12.134	10.635	9.394	8.853	7.904	7.103	6.424	5.842	5.583	5.342	4.910
14	13.004	11.296	9.899	9.295	8.244	7.367	6.628	6.002	5.724	5.468	5.008
15	13.865	11.938	10.380	9.712	8.559	7.606	6.811	6.142	5.847	5.575	5.092
16	14.718	12.561	10.838	10.106	8.851	7.824	6.974	6.265	5.954	5.668	5.162
17	15.562	13.166	11.274	10.477	9.122	8.022	7.120	6.373	6.047	5.749	5.222
18	16.398	13.754	11.690	10.828	9.372	8.201	7.250	6.467	6.128	5.818	5.273
19	17.226	14.324	12.085	11.158	9.604	8.365	7.366	6.550	6.198	5.877	5.316
20	18.046	14.877	12.462	11.470	9.818	8.514	7.469	6.623	6.259	5.929	5.353

Year	20%	22%	24%	25%	26%	28%	30%	35%	40%	45%	50%
1	0.833	0.820	0.806	0.800	0.794	0.781	0.769	0.741	0.714	0.690	0.667
2	1.528	1.492	1.457	1.440	1.424	1.392	1.361	1.289	1.224	1.165	1.111
3	2.106	2.042	1.981	1.952	1.923	1.868	1.816	1.696	1.589	1.493	1.407
4	2.589	2.494	2.404	2.362	2.320	2.241	2.166	1.997	1.849	1.720	1.605
5	2.991	2.864	2.745	2.689	2.635	2.532	2.436	2.220	2.035	1.876	1.737
6	3.326	3.167	3.020	2.951	2.885	2.759	2.643	2.385	2.168	1.983	1.824
7	3.605	3.416	3.242	3.161	3.083	2.937	2.802	2.508	2.263	2.057	1.883
8	3.837	3.619	3.421	3.329	3.241	3.076	2.925	2.598	2.331	2.108	1.922
9	4.031	3.786	3.566	3.463	3.366	3.184	3.019	2.665	2.379	2.144	1.948
10	4.192	3.923	3.682	3.571	3.465	3.269	3.092	2.715	2.414	2.168	1.965
11	4.327	4.035	3.776	3.656	3.543	3.335	3.147	2.752	2.438	2.185	1.977
12	4.439	4.127	3.851	3.725	3.606	3.387	3.190	2.779	2.456	2.196	1.985
13	4.533	4.203	3.912	3.780	3.656	3.427	3.223	2.799	2.468	2.204	1.990
14	4.611	4.265	3.962	3.824	3.695	3.459	3.249	2.814	2.477	2.210	1.993
15	4.675	4.315	4.001	3.859	3.726	3.483	3.268	2.825	2.484	2.214	1.995
16	4.730	4.357	4.033	3.887	3.751	3.503	3.283	2.834	2.489	2.216	1.997
17	4.775	4.391	4.059	3.910	3.771	3.518	3.295	2.840	2.492	2.218	1.998
18	4.812	4.419	4.080	3.928	3.786	3.529	3.304	2.844	2.494	2.219	1.999
19	4.843	4.442	4.097	3.942	3.799	3.539	3.311	2.848	2.496	2.220	1.999
20	4.870	4.460	4.110	3.954	3.808	3.546	3.316	2.850	2.497	2.221	1.999

APPENDIX B

COMPLETED WORK TABLES

TABLE 11

OPTION 1
FINANCIAL CASH FLOW
COSTS AND BENEFITS PER ACRE

	Years From Project Start			
	Year 1		Years 2 through 10	
Without Project				
Gross Benefits		800		800
Gross Costs		100		100
Net Benefits		700		700
With Project				
Gross Benefits		800		2,000
Cost Components				
Investment (per-acre well cost)	2,600		0	
Fuel (per-acre share)	0		100	
Usual fertilizer and pesticides	100		100	
Extra fertilizer and pesticides	0		100	
Gross Costs		2,700		300
Net Benefits		-1,900		1,700
Changes Due To Project				
Incremental Benefits	0		1,200	
Incremental Costs	2,600		200	
CASH FLOW	-2,600		1,000	

TABLE 12

OPTION 2
FINANCIAL CASH FLOW
COSTS AND BENEFITS PER ACRE

	Years From Project Start			
	Year 1		Years 2 through 10	
Without Project				
Gross Benefits		800		800
Gross Costs		100		100
Net Benefits		700		700
With Project				
Gross benefits		800		2,900
Cost Components				
Investment (per-acre well cost)	3,000		0	
Fuel (per-acre share)	0		100	
Usual fertilizer and pesticides	100		100	
Extra fertilizer and pesticides	0		100	
Gross Costs		3,100		300
Net Benefits		-2,300		1,700
Changes Due To Project				
Incremental Benefits	0		1,200	
Incremental Costs	3,000		200	
CASH FLOW	-3,000		1,000	

TABLE 13

OPTION 1
BENEFIT-COST RATIO

Discount Rate 5%

YEAR			INCREMENTAL COSTS	PRESENT WORTH OF INCREMENTAL COSTS	INCREMENTAL BENEFITS	PRESENT WORTH OF INCREMENTAL BENEFITS
1	discount factor	.95	2,600	2,470	0	0
2 through 10	adjusted annuity factor	6.77	200	1,354	1,200	8,124
Total				3,824		8,124

$$\text{BENEFIT/COST RATIO} = \frac{\text{Present Worth of Incremental Benefits}}{\text{Present Worth of Incremental Costs}} = \frac{8,124}{3,824} = 2.12$$

TABLE 14

OPTION 2
BENEFIT-COST RATIO

Discount Rate 5%

YEAR			INCREMENTAL COSTS	PRESENT WORTH OF INCREMENTAL COSTS	INCREMENTAL BENEFITS	PRESENT WORTH OF INCREMENTAL BENEFITS
1	discount factor	.95	3,000	2,850	0	0
2 through 10	adjusted annuity factor	6.77	200	1,354	1,200	8,124
Total				4,204		8,124

$$\text{BENEFIT/COST RATIO} = \frac{\text{Present Worth of Incremental Benefits}}{\text{Present Worth of Incremental Costs}} = \frac{8,124}{4,204} = 1.93$$

TABLE 15

OPTION 1
NET PRESENT WORTH

Discount Rate 5%

YEAR			INCREMENTAL BENEFITS	INCREMENTAL COSTS	ANNUAL CASH FLOW	PRESENT WORTH OF CASH FLOW
1	discount factor	.95	0	2,600	-2,600	-2,470
2 through 10	adjusted annuity factor	6.77	1,200	200	1,000	6,770
				NET PRESENT WORTH		4,300

TABLE 16

OPTION 2
NET PRESENT WORTH

Discount Rate 5%

YEAR			INCREMENTAL BENEFITS	INCREMENTAL COSTS	ANNUAL CASH FLOW	PRESENT WORTH OF CASH FLOW
1	discount factor	.95	0	3,000	-3,000	-2,850
2 through 10	adjusted annuity factor	6.77	1,200	200	1,000	6,770
				NET PRESENT WORTH		3,920

TABLE 17

OPTION 1
INTERNAL RATE OF RETURN

I. Calculate Net Present Worth with different Discount Rates until you have a POSITIVE and a NEGATIVE NPW.

CASH FLOW YEAR 1 -2,600 CASH FLOW YEARS 2-10 1,000

Trial Discount Rate	Discount Factor Year 1	Present Worth Year 1	Adjusted Annuity Factor Years 2-10	Present Worth Years 2-10	Net Present Worth at Trial Discount Rate
10%	.91	-2,366	5.24	5,240	2,874
20%	.83	-2,158	3.36	3,360	1,202
30%	.77	-2,002	2.32	2,320	318
35%	.74	-1,924	1.97	1,970	46
40%	.71	-1,846	1.7	1,700	- 146

II. TRANSFER FROM TABLE

Low TDR 35

High TDR 40

NPW at Low TDR 46

NPW at High TDR -146

III. CALCULATE

High TDR - Low TDR 5

NPW at Low TDR + Absolute Value of NPW at High TDR 192

IV. INTERPOLATE

$$IRR = \text{Low TDR} + \left[(\text{High TDR} - \text{Low TDR}) \times \frac{\text{NPW at Low TDR}}{\text{NPW at Low TDR} + \text{Absolute Value of NPW at High TDR}} \right]$$

$$IRR = 35 + \left[5 \times \frac{46}{192} \right]$$

$$IRR = 35 + \left[5 \times .24 \right]$$

$$IRR = 35 + 1.2$$

$$IRR = 36.2$$

TABLE 18

OPTION 2
INTERNAL RATE OF RETURN

I. Calculate Net Present Worth with different Discount Rates until you have a POSITIVE and a NEGATIVE NPW.

CASH FLOW YEAR 1 -3,000 CASH FLOW YEARS 2-10 1,000

Trial Discount Rate	Discount Factor Year 1	Present Worth Year 1	Adjusted Annuity Factor Years 2-10	Present Worth Years 2-10	Net Present Worth at Trial Discount Rate
10%	.91	-2,730	5.24	5,240	2,510
20%	.83	-2,490	3.36	3,360	870
30%	.77	-2,310	2.32	2,320	10
35%	.74	-2,220	1.97	1,970	- 250

II. TRANSFER FROM TABLE

Low TDR 30

High TDR 35

NPW at Low TDR 10

NPW at High TDR -250

III. CALCULATE

High TDR - Low TDR 5

NPW at Low TDR + Absolute Value of NPW at High TDR 260

IV. INTERPOLATE

$$IRR = \text{Low TDR} + \left[\text{High TDR} - \text{Low TDR} \times \frac{\text{NPW at Low TDR}}{\text{NPW at Low TDR} + \text{Absolute Value of NPW at High TDR}} \right]$$

$$IRR = 30 + \left[5 \times \frac{10}{260} \right]$$

$$IRR = 30 + \left[5 \times .038 \right]$$

$$IRR = 30 + .19$$

$$IRR = 30.19$$

TABLE 20

OPTION 1
FINANCIAL CASH FLOW
COSTS AND BENEFITS PER WELL

	Years From Project Start			
	Year 1		Years 2 through 10	
Without Project				
Gross Benefits		80,000		80,000
Gross Costs		10,000		10,000
Net Benefits		70,000		70,000
With Project				
Gross Benefits		80,000		200,000
Cost Components				
Investment (per well)	260,000		0	
Fuel (per well)	0		10,000	
Usual fertilizer and pesticides	10,000		10,000	
Extra fertilizer and pesticides	0		10,000	
Gross Costs		270,000		30,000
Net Benefits		-190,000		170,000
Changes Due To Project				
Incremental Benefits		0		120,000
Incremental Costs		260,000		20,000
CASH FLOW		-260,000		100,000

TABLE 21

OPTION 2
FINANCIAL CASH FLOW
COSTS AND BENEFITS PER WELL

	Years From Project Start			
	Year 1		Years 2 through 10	
Without Project				
Gross Benefits		64,000		64,000
Gross Costs		8,000		8,000
Net Benefits		56,000		56,000
With Project				
Gross Benefits		64,000		160,000
Cost Components				
Investment (per well)	240,000		0	
Fuel (per well)	8,000		8,000	
Usual fertilizer and pesticides	8,000		8,000	
Extra fertilizer and pesticides			8,000	
Gross Costs		256,000		24,000
Net Benefits		-192,000		136,000
Changes Due To Project				
Incremental Benefits		0		96,000
Incremental Costs		248,000		16,000
CASH FLOW		-248,000		80,000

TABLE 22

SHADOW PRICING WORKSHEET
OPTION 1

Transfer: information from scenario for breakdown of well investment costs (pp. 29-30)

: other cost and benefit data from per-well financial cash flow (p. 44)

: shadow pricing factors from table 19

Multiply the financial value by the shadow pricing factor to get the economic value. When no shadow price has been set, use the financial value - shadow pricing factor = 1.

GROSS BENEFITS

Value of Rice Yield	Financial Benefits	Shadow Pricing Factor	Economic Benefits
Without project and Year 1 with project	80,000	.92	73,600
Years 2-10 with project	200,000	.92	184,000

INVESTMENT COSTS

Component	Financial Cost	Shadow Pricing Factor	Economic Cost
Imported equipment	130,000	1.5	195,000
Foreign contractors	40,000	1.5	60,000
Domestic equipment	30,000	1	30,000
Skilled domestic labor	50,000	1	50,000
Unskilled domestic labor	10,000	.5	5,000
TOTAL	260,000		340,000

RECURRENT COSTS

	Financial Cost	Shadow Pricing Factor	Economic Cost
Without Project and Year 1 With Project: fertilizer and pesticide	10,000	2	20,000
Years 2-10 with project: pump operation	10,000	2	20,000
Fertilizer and pesticide	20,000	2	40,000

TABLE 23

SHADOW PRICING WORKSHEET
OPTION 2

Transfer: information from scenario for breakdown of well investment costs (pp. 30-31)

: other cost and benefit data from per-well financial cash flow (p. 45)

: shadow pricing factors from table 19

Multiply the financial value by the shadow pricing factor to get the economic value. When no shadow price has been set, use the financial value - shadow pricing factor = 1.

GROSS BENEFITS

Value of Rice Yield	Financial Benefits	Shadow Pricing Factor	Economic Benefits
Without project and Year 1 with project	64,000	.92	58,880
Years 2-10 with project	160,000	.92	147,200

INVESTMENT COSTS

Component	Financial Cost	Shadow Pricing Factor	Economic Cost
Imported equipment	50,000	1.5	75,000
Foreign contractors	20,000	1.5	30,000
Domestic equipment	100,000	1	100,000
Skilled domestic labor	40,000	1	40,000
Unskilled domestic labor	30,000	.5	15,000
TOTAL	240,000		260,000

RECURRENT COSTS

	Financial Cost	Shadow Pricing Factor	Economic Cost
Without Project and Year 1 With Project: fertilizer and pesticide	8,000	2	16,000
Years 2-10 with project: pump operation	8,000	2	16,000
Fertilizer and pesticide	16,000	2	32,000

TABLE 24

OPTION 1
ECONOMIC CASH FLOW
COSTS AND BENEFITS PER WELL

	Years From Project Start			
	Year 1		Years 2 through 10	
Without Project				
Gross Benefits		73,600		73,600
Gross Costs		20,000		20,000
Net Benefits		53,600		53,600
With Project				
Gross Benefits		73,600		184,000
Cost Components				
Investment (per well)	340,000			
Fuel (per well)			20,000	
Usual fertilizer and pesticides	20,000		20,000	
Extra fertilizer and pesticides			20,000	
Gross Costs		360,000		60,000
Net Benefits		-286,400		124,000
Changes Due To Project				
Incremental Benefits		0		110,400
Incremental Costs		340,000		40,000
CASH FLOW		-340,000		70,400

TABLE 25

OPTION 2
ECONOMIC CASH FLOW
COSTS AND BENEFITS PER WELL

	Years From Project Start			
	Year 1		Years 2 through 10	
Without Project				
Gross Benefits		58,880		58,880
Gross Costs		16,000		16,000
Net Benefits		42,880		42,880
With Project				
Gross Benefits		58,880		147,200
Cost Components				
Investment (per well)	260,000			
Fuel (per well)			16,000	
Usual fertilizer and pesticides	16,000		16,000	
Extra fertilizer and pesticides			16,000	
Gross Costs		276,000		48,000
Net Benefits		-217,120		99,200
Changes Due To Project				
Incremental Benefits		0		88,320
Incremental Costs		260,000		32,000
CASH FLOW		-260,000		56,320

TABLE 26

OPTION 1
NET PRESENT WORTH

Discount Rate 10% Units T.1,000

YEAR		INCREMENTAL BENEFITS	INCREMENTAL COSTS	ANNUAL CASH FLOW	PRESENT WORTH OF CASH FLOW
1	discount factor .91	0	340	-340	-309
2 through 10	adjusted annuity factor 5.24	110	40	70	367
			NET PRESENT WORTH		58

TABLE 27

OPTION 2
NET PRESENT WORTH

Discount Rate 10% Units T.1,000

YEAR		INCREMENTAL BENEFITS	INCREMENTAL COSTS	ANNUAL CASH FLOW	PRESENT WORTH OF CASH FLOW
1	discount factor .91	0	260	-260	-237
2 through 10	adjusted annuity factor 5.24	88	32	56	293
			NET PRESENT WORTH		56

TABLE 28

OPTION 1
INTERNAL RATE OF RETURN

Units T.1,000

I. Calculate Net Present Worth with different Discount Rates until you have a POSITIVE and a NEGATIVE NPW.

CASH FLOW YEAR 1 -340 CASH FLOW YEARS 2-10 70

Trial Discount Rate	Discount Factor Year 1	Present Worth Year 1	Adjusted Annuity Factor Years 2-10	Present Worth Years 2-10	Net Present Worth at Trial Discount Rate
10%	.91	-309	5.24	367	58
15%	.87	-296	4.15	290	- 6

II. TRANSFER FROM TABLE

Low TDR 10

High TDR 15

NPW at Low TDR 58

NPW at High TDR - 6

III. CALCULATE

High TDR - Low TDR 5

NPW at Low TDR + Absolute Value of NPW at High TDR 64

IV. INTERPOLATE

$$IRR = \text{Low TDR} + \left[\text{High TDR} - \text{Low TDR} \times \frac{\text{NPW at Low TDR}}{\text{NPW at Low TDR} + \text{Absolute Value of NPW at High TDR}}\right]$$

$$IRR = 10 + \left[5 \times \frac{58}{64}\right]$$

$$IRR = 10 + \left[5 \times .91\right]$$

$$IRR = 10 + 4.55$$

$$IRR = 14.55$$

TABLE 29

OPTION 2
INTERNAL RATE OF RETURN

Units T.1,000

I. Calculate Net Present Worth with different Discount Rates until you have a POSITIVE and a NEGATIVE NPW.

CASH FLOW YEAR 1 -260 CASH FLOW YEARS 2-10 56

Trial Discount Rage	Discount Factor Year 1	Present Worth Year 1	Adjusted Annuity Factor Years 2-10	Present Worth Years 2-10	Net Present Worth at Trial Discount Rate
15%	.87	-226	4.15	232	6
20%	.83	-216	3.36	188	-28

II. TRANSFER FROM TABLE

Low TDR 15

High TDR 20

NPW at Low TDR 6

NPW at High TDR 28

III. CALCULATE

High TDR - Low TDR 5

NPW at Low TDR + Absolute Value of NPW at High TDR 34

IV. INTERPOLATE

$$IRR = \text{Low TDR} + \left[\text{High TDR} - \text{Low TDR} \times \frac{\text{NPW at Low TDR}}{\text{NPW at Low TDR} + \text{Absolute Value of NPW at High TDR}}\right]$$

$$IRR = 15 + \left[5 \times \frac{6}{34}\right]$$

$$IRR = 15 + \left[5 \times .18\right]$$

$$IRR = 15 + .9$$

$$IRR = 15.9$$

TABLE 31

Option 1 *Units* 1000 taka

Economic NPW per well 58

Distribution-weighted Project NPW = 58 x 500 x .67 = 19,430

+ 58 x 500 x .8 = 23,200

= 42,630

Option 2

Economic NPW per well 56

Distribution-weighted Project NPW = 56 x 200 x .67 = 7,504

+ 56 x 200 x .8 = 8,960

+ 56 x 200 x 1 = 11,200

+ 56 x 200 x 1.3 = 14,560

+ 56 x 200 x 2 = 22,400

= 64,624