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COST-EFFECTIVENESS ANALYSIS

Jack Reynolds
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COST-EFFECTIVENESS ANALYSIS

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PRICOR

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PREFACE

Primary Health Care Operations Research (PRICOR) is a project of the Center for Human Services and is funded by the United States Agency for International Development (AID) under a cooperative agreement (AID/DSPE-5920-A-00-1048-00). The Center for Human Services is a nonprofit, development services organization specializing in the design and management of programs that address the basic needs of people in developing countries and the United States. PRICOR's objective is to promote operations research as a tool to help program managers and policymakers find solutions to problems they encounter in designing and operating primary health care (PHC) programs.

This project's activities include: funding and monitoring country studies; sponsoring workshops and conferences; conducting methodological and comparative studies; and disseminating the findings of sponsored research. PRICOR is particularly interested in research designed to overcome problems that limit the expansion of essential PHC services to high-risk populations in rural and peri-urban communities. Consequently, PRICOR has concentrated on operations research to find solutions to problems in four priority areas:

- Community health workers
- Community-based commodity distribution
- Community financing
- Community organization

Operations research provides a systematic approach to problemsolving. In operations research, rather than relying on the costly process of trial-and-error, a well-defined plan of analysis is used to select the best of several possible alternatives. A specific operational problem is first defined and analyzed. Alternative solutions are developed and evaluated to identify those that are most appropriate and feasible. Recommendations are then made for testing, or in some cases directly implementing, the best solution(s).

This is one in a series of five monographs on operations research that was prepared by PRICOR staff and consultants for researchers in the developing world who are interested in learning more about this approach and applying it to their own primary health care programs. The five monographs in the series are:

- Methodology Papers

  1. Operations Research Methods: A General Approach in Primary Health Care
  2. Operations Research Methods: Cost-Effectiveness Analysis

- Issue Papers

  1. Operations Research Issues: Community Financing
  2. Operations Research Issues: Community Health Workers
  3. Operations Research Issues: Community Organization

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ABBREVIATIONS USED IN TEXT

AID	Agency for International Development (USAID)
APHA	American Public Health Association
CEA	Cost-Effectiveness Analysis
CF	Community Financing
CHW	Community Health Worker
EPI	Expanded Program on Immunization
MCH	Maternal and Child Health
MOH	Ministry of Health
ORS	Oral Rehydration Salts
ORT	Oral Rehydration Therapy
PHC	Primary Health Care
PRICOR	Primary Health Care Operations Research
VHC	Village Health Committees
WHO	World Health Organization

INTRODUCTION

Primary health care is gaining acceptance as a strategy for bringing basic health services to all people in developing nations who do not have access to such services at this time. Primary health care programs can have a significant impact on health by focusing on a limited number of health problems that, although they are the greatest contributors to excess morbidity and premature mortality, are preventable by means of simple, relatively low-cost interventions.

Diarrhea, respiratory infections, malnutrition, and contagious diseases are among the most serious health problems in developing countries. They result in high rates of infant, child, and maternal mortality and morbidity, particularly in rural areas and in the surroundings of urban centers, where organized health services are most limited. Ironically, much of this suffering is avoidable, because a few primary health care interventions could dramatically reduce these problems if ways could be found to reach the target populations--particularly women and children--with such needed primary health care services as immunizations, oral rehydration therapy, growth monitoring, family planning, malaria prophylaxis, water supply, environmental sanitation, and antepartum and perinatal care.

In 1978, the International Conference on Primary Health Care was convened at Alma-Ata in the Soviet Union. At this historic event attended by representatives of 134 nations, primary health care was endorsed as a strategy for making fundamental health services universally accessible to the world's population. The Declaration of Alma-Ata defines primary health care as:

> . . . essential health care based on practical, scientifically sound and socially acceptable methods and technology made universally accessible to individuals and families in the community through their full participation and at a cost that the community and country can afford . . . . [Primary health care] addresses the main health problems in the community, providing promotive, preventive, curative and rehabilitative services accordingly . . . [it] includes at least: education concerning prevailing health problems and the methods of preventing and controlling them, promotion of food supply and proper nutrition; an adequate supply of safe water and basic sanitation; maternal and child health care, including family planning; immunization against major infectious diseases; appropriate treatment of common diseases and injuries; and provision of essential drugs.(1)

Among those organizations helping to find ways to achieve this goal is the Agency for International Development (AID), which has supported numerous primary health care projects around the world. These projects, extensively documented in a recent American Public Health Association publication, have demonstrated the efficacy of primary health care in reducing premature mortality and excess morbidity.(2)

The Agency for International Development has been particularly interested in finding ways to expand coverage of mothers and children in rural and periurban areas with such essential primary health care services as immunizations and oral rehydration therapy, among others. However, AID and other international donors have learned from experience that meeting this objective is not a simple matter.

Role of Operations Research in Primary Health Care

A number of operational issues need to be resolved before primary health care can become universally available. For example, the Alma-Ata Conference report noted that:

> Enough is already known about primary health care for much of it to be put into practice immediately. However, much still needs to be learned about its application under local conditions. and during its operation, control and evaluation questions will arise which will require research. These may be related to such questions as the organization of primary health care within communities and of supporting services; the mobilization of community support and participation; the best ways of applying (existing and appropriate) technology; the planning for and training of community health workers, their supervision, their remuneration and their career structure; and methods of financing primary health care.(3)

Recognizing the importance of research into the operation of primary health care delivery, the AID Office of Health funded PRICOR to help primary health care program managers and policymakers find solutions to such problems through operations research. PRICOR has defined operations research as a problemsolving process consisting of three phases:

1. Systematic analysis of the operational problem;
2. Application of the most appropriate analytical methods to identify the best solution(s) to that problem; and
3. Validation of the solution(s).

Although operations research has not yet been widely used as an analytical and decisionmaking tool to improve health services in developing countries, it can be applied to examine a number of issues pertinent to primary health care service delivery.

For example, operations research can examine the advantages and disadvantages of completely different primary health care strategies, such as delivering service by means of community-based, clinic-based, or mobile programs. Operations research can also help determine the best way to structure a particular primary health care program (e.g., how each service can be financed), or to identify how existing services can be improved (e.g., how more children can be immunized within a given budget).

Cost-effectiveness analysis (CEA) is one technique that often is used in operations research. When used for primary health care planning, it can help policymakers and program managers examine alternative ways of achieving a given objective and enable them to select the method that uses available resources most effectively. This paper describes CEA methods and illustrates how CEA can be applied as a research tool to a variety of operational issues in the design and delivery of primary health care programs.

In this paper, the first two chapters give a brief overview of CEA for those researchers and decisionmakers who may be interested in learning what this technique is and how it can be applied to planning and improving primary health care programs. Chapter I discusses the basic principles of CEA, including its benefits and limitations. Chapter II offers a step-by-step approach to the design and conduct of a CEA study. Six steps are described, and each is illustrated with a case study in which CEA is used to find a solution to an operational problem in primary health care programming.

Four appendices are included to provide detailed instructions for those researchers who are interested in carrying out a CEA. Appendix A describes the principles and procedures for determining the costs of PHC alternatives. Appendix B describes the principles used to measure the effectiveness of selected alternatives. Appendix C shows how to analyze costs, effectiveness, and the cost-effectiveness of primary health care alternatives. Finally, Appendix D discusses refinements that can be made in basic CEA procedures.

This manual was prepared as a practical guide for primary health care program managers who are interested in doing cost-effectiveness analysis to aid in decisionmaking. Sections of it may also be of use to those researchers who need a reference manual on cost analysis or effectiveness measurement.

NOTES

1. "Declaration of Alma-Ata," Primary Health Care, Report of the International Conference on Primary Health Care, Alma-Ata, USSR, 6-12 September 1978, jointly sponsored by the World Health Organization and the United Nations Children's Fund (Geneva: WHO, 1978), pp. 3-4.

2. Primary Health Care: Progress and Problems. An Analysis of 52 AID-Assisted Projects (Washington, DC: APHA, 1982).

3. World Health Organization and United Nations Children's Fund, Alma-Ata 1978, op. cit., pp. 71-72.

CHAPTER I

BASIC PRINCIPLES OF COST-EFFECTIVENESS ANALYSIS

CHAPTER I. BASIC PRINCIPLES OF COST-EFFECTIVENESS ANALYSIS

Cost-effectiveness analysis (CEA) is an analytical tool often used in operations research to help decisionmakers assess and compare the costs and effectiveness of alternative ways of achieving an objective. It is " . . . a technique for identifying the most effective use of limited resources."(1)

People use a form of CEA in everyday life to help them make decisions, because they are continually confronted with choices involving tradeoffs between costs and benefits such as: "Should I eat dinner at home or go to a restaurant?" "Should I drive to work, take the bus, or use my bicycle?"

Cost-effectiveness analysis is a formal process for organizing information so that the costs of alternatives and their relative effectiveness in meeting a given objective can be compared systematically. CEA actually involves three distinct processes, which will be discussed in Chapter II. They are:

1. An analysis of the costs of each alternative
2. An analysis of each alternative's effectiveness
3. An analysis of the relationship between the costs and effectiveness of each alternative, usually expressed as a ratio. (See table 1-1 for an example.)

The cost-effectiveness (CE) ratio is calculated by dividing the cost of an alternative, which is usually expressed in monetary terms, by the effectiveness of that alternative, which usually is expressed in nonmonetary terms.*

DEFINITIONS

Because a number of key terms are used throughout this paper, brief definitions of these terms are given below. Others can be found in the glossary.

- Cost--Although people usually think of cost as the monetary value of a commodity or service, cost has a technical meaning to economists. According to Warner and Luce:

  In general, cost-effectiveness rests on the basic economic concept of opportunity costs: that is, the true cost of an activity is the value of the alternative endeavor that might have been undertaken with the same resources.(2)

- Effective--To produce the desired result, to accomplish the correct end, or to secure the relevant outcome.(3)

- Cost-effective--To achieve an objective with the minimum expenditure of resources.

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* Cost-benefit analysis (CBA) is often confused with CEA; however, in this method, the effect (the denominator) is expressed in monetary terms. In table 1-1, the economic value of a life saved would have to be determined and then multiplied by the number of lives saved. The results would show how the benefit (in monetary terms) compares with the cost (also in monetary terms). Some analysts invert the numerator and denominator to compute a "benefit/cost ratio." Health benefits usually are difficult to express in monetary terms, which makes this type of analysis difficult to undertake.

Table 1-1.--Sample Cost-Effectiveness Analysis

Alternatives	Costs	Effectiveness	CE Ratio
A	$25,000	100 lives saved	$25,000/100 = $250/life
B	$25,000	15 lives saved	$25,000/15 = $1,677/life

As an analytical tool, CEA has a number of strengths, and several limitations.

> Most important is that it merely requires combining cost data with effectiveness data . . . to create a cost-effectiveness comparison. Further, it lends itself well to an evaluation of alternatives that are being considered for accomplishing a particular . . . goal. Its one major disadvantage is that one cannot compare CE ratios among alternatives with different goals (e.g., . . . education vs. health), nor can one make a determination of whether a program is worthwhile [even when] its benefits exceed its costs. . . . It is possible that a program with the lowest cost . . . is a poor investment [because] its costs are still very high [and] society would benefit more if the resources were used some other way.(4)

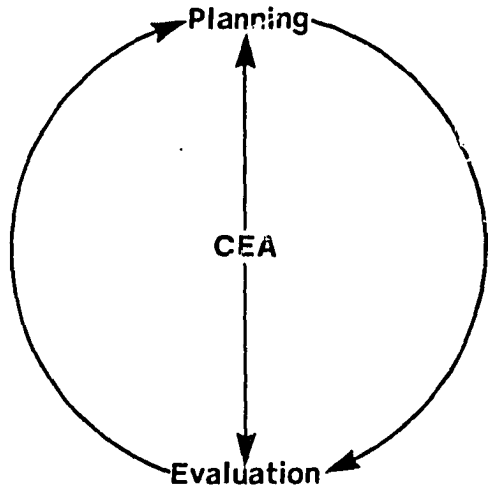
USES OF COST-EFFECTIVENESS ANALYSIS

Cost-effectiveness analysis is used primarily as a decisionmaking tool to help policymakers and program managers select a future course of action. Although it often is used to evaluate completed programs, the ultimate use of this research method should be to help decisionmakers decide what to do in the future. Thus, a retrospective CEA (e.g., an evaluation of immunization programs that have already been conducted) is really used to estimate the cost-effectiveness of carrying out these same alternatives in the future. Similarly, a prospective CEA (e.g., an evaluation of possible immunization strategies that have not yet been implemented) is really an estimate of what the costs and effectiveness of the alternatives are likely to be.

In actual operation, those costs and effects typically vary from the initial estimates, and the CEA needs to be revised to reflect actual experience. Thus, CEA can be used both prospectively (in planning) and retrospectively (in evaluation). Ideally, it would be used for both purposes, as depicted in figure 1-1.

CEA has only recently been applied to primary health care in the developing world. Several papers prepared in the past few years have demonstrated the versatility of the technique. Grosse, et al., have shown how the expected costs and effects of alternative health programs can be simulated.(5) Barnum has shown how CEA could be used to study diarrhea treatment alternatives, communicable diseases programs, and immunization programs.(6,7) Reinke, as well as Gillespie, et al., have shown how CEA can be applied to family planning service alternatives.(8, 9, 10) Parker has shown how CEA can be used to improve nutrition services,(11) and Shepard and Cash have developed a manual for using CEA in oral rehydration programs.(12, 13)

Figure 1-1.--Role of Cost-Effectiveness in Planning and Evaluation



Use of CEA To Compare Alternatives

Cost-effectiveness analysis can be used to answer many different types of questions regarding which is the least expensive or most effective alternative. It also can be used to help make a variety of different decisions. For example, it can be used by planners and policymakers to help select an overall primary health care approach or strategy, and by managers within a given program to make decisions about payment and service delivery options. Examples of CEA at various levels of decisionmaking are shown in table 1-2 and discussed briefly below.

Evaluate alternative programs designed to achieve same goal. When initially planning a primary health care strategy, policymakers usually have to decide which of several competing programs would be the best investment given their national and local needs. Usually they have a variety of choices, a number of ways to use their resources to bring down mortality and morbidity, and they often must decide which approach would be best. Cost-effectiveness analysis can be used to make such decisions because it enables policymakers to compare different primary health care services in terms of what each will cost and what each will produce in terms of lives saved or deaths averted. Walsh and Warren used CEA to argue that

> Until comprehensive primary health care can be made available to all, services aimed at the few most important diseases (selective primary health care) may be the most effective means of improving the health of the greatest number of people.(14)

The selective approach to primary care concentrates on

> . . . measles and . . . DPT vaccination for children over six months, tetanus toxoid to all women of childbearing age, encouragement of long-term breastfeeding, provision of chloroquine for episodes of fever in children under three years old in areas where malaria is prevalent and, finally oral rehydration packets and instruction.(15)

Table 1-2.--Sample Uses for Cost-Effectiveness Analysis

CEA Use and Sample Research Question	Sample Alternatives for Comparison		
• To evaluate alternative programs designed to achieve same goal			
-- Which is the most cost-effective program for saving the lives of children under age 5?	Immunization*	Malaria Control	Water and Sanitation
• To evaluate alternative means to achieve a PHC program objective			
-- Which is the most cost-effective immunization program?	DPT	Measles*	Polio
-- Which is the most cost-effective measles immunization strategy?	Mobile Units	MCH Clinic*	Annual Campaign
• To evaluate tradeoffs in program size, scope, composition			
-- What is the most cost-effective composition for an MCH immunization team?	1 MD 1 Nurse	1 Nurse 2 Aux.	1 MD* 2 Aux.

* Represents the alternative shown by means of a hypothetical CEA to be the preferred selection.

The Walsh and Warren study showed that selective primary health care would cost about $0.25 (U.S.) per capita, while the cost per death averted was $200-$250. Thus, the selective primary health care approach was shown to be both more cost-effective than the other programs considered and less costly as well. Table 1-3 shows the data on which Walsh and Warren based their conclusions. This study applies to developing nations generally. Similar analyses could be undertaken in individual nations and within nations in areas with unique health problems and needs.

Evaluate alternative means for a given program to achieve its objective(s). Sometimes program managers have to decide which is the most cost-effective way to implement a given program. Again, there may be a number of choices. For example, immunization could be provided in several ways. A CEA would help a manager decide which would be best by examining the costs and expected effectiveness of each alternative.

Table 1-3.--Estimated Cost-Effectiveness of Selected Health Programs

Program	Per Capita Costs ($US)	Cost per Infant and/or Child Death Averted ($US)
Selective PHC	0.25	200 - 250
Mosquito Control for Malaria	2.00	600
Comprehensive PHC	2.00	700
Community Water and Sanitation	30-54	3,600 - 4,300

Source: Julia A. Walsh and Kenneth S. Warren, "Selective Primary Health Care: An Interim Strategy for Disease Control in Developing Countries," The New England Journal of Medicine, November 1, 1979, p. 973.

Table 1-4 illustrates a comparison of three strategies for immunizing 15,000 children, using hypothetical data: an annual immunization campaign; periodic mobile immunization teams; and continual provision of immunization through maternal and child health (MCH) clinics. This analysis shows that the MCH strategy would be the most cost-effective of the three. It would result in all of the children being immunized for an average of $3 each, $20,000 less in total costs than the alternative that ranks next in order of cost.

Evaluate the tradeoffs in varying the size, scope, or composition of a given strategy. Given a selected strategy, program planners can also use CEA to identify the most cost-effective size, scope, or composition for that strategy. This is an important use of CEA because decisions often have to be made about whether to have several small projects or a large one and whether to staff a project one way or another. Table 1-5 shows an analysis of two different mixes of personnel for providing immunizations through maternal and child health clinics. These illustrative data indicate that Alternative B would be more cost-effective. For the same amount of money ($45,000), the physician and two auxiliary personnel can immunize 5,000 more children than the physician-nurse team.

Table 1-4.--CEA of Alternative Immunization Strategies

Alternative	Costs	Effectiveness	CE Ratio
Campaign	$75,000	15,000	$5.00/immunization
MCH clinics	$45,000	15,000	$3.00/immunization
Mobile units	$65,000	15,000	$4.33/immunization

Table 1-5.--CEA of Alternative Mixes of MCH Immunization Personnel

	Alternative	Costs	Effectiveness	CE Ratio
A.	MD + nurse	$45,000	15,000	$3.00/immunization
B.	MD + 2 auxiliary personnel	$45,000	20,000	$2.25/immunization

Use of CEA To Identify the Optimum Alternative

In all of the examples mentioned thus far, CEA was used to examine a discrete number of known alternatives (e.g., to compare costs and effectiveness of immunization and malaria control). In the last example, the planner could choose either a physician-nurse team or a physician-auxiliary personnel team. Those alternatives are distinct and identified. In operations research, CEA is also used to compute which of many possible alternatives is the most cost-effective when alternatives are neither discrete nor known; that is, when the variable is a continuous one and the objective is to find the best value for that variable. For example, CEA can be used to determine the optimum class size for a training course by computing the costs of various class sizes and their effectiveness (e.g., in terms of skills learned) and comparing the two in a table or graph.

Table 1-6 shows that the total cost of training increases as class size increases, but the cost per student trained decreases. If these are the only relevant variables, then the largest class (40 students) is the most cost-effective. However, if skills acquired is important, then the smallest class (10 students) will produce the highest learning level. The most cost-effective class size that will result in the greatest learning per unit of cost is 25 students (77 percent of skills learned at a cost of $677 per unit of skill acquired).

Table 1-6.--Illustrative Use of CEA to Determine Optimum Training Class Size

Class Size (A)	Cost (B)	Cost per Student Trainee (C = B/A)	Learning Level(%) Acquired (D)	Units of Skill (E = A x C)	Cost per Unit Skill (F = B/D)
10	$ 7,200	$720	.90	9.0	$800
15	9,400	627	.84	12.6	746
20	11,400	570	.82	16.4	695
25	13,000	520	.77	19.2	677
30	14,600	487	.66	19.8	737
35	15,900	454	.54	18.9	841
40	17,100	428	.46	18.4	929

REQUIREMENTS OF A COST-EFFECTIVENESS ANALYSIS

A researcher who plans to undertake a CEA must insure that four requirements are met. Each is discussed briefly below.

Requirement 1. There must be a defined objective. The decisionmaker must specify an objective; that is, a desired outcome. This can be a desirable level of service, a change in behavior, or a health impact goal. The objective must also be quantified, so it can be measured. Appendix B discusses this topic in greater detail.

Requirement 2. Alternative means of achieving that objective must be identified. Cost-effectiveness analysis is a comparative technique. Therefore, alternative ways of achieving the objective must be identified so that they can be compared. There must be at least two alternatives. One cannot do a CEA of a single alternative, because there would be nothing with which to compare it.

> Good alternatives should be identified and compared directly to each other to determine which is best. A common mistake is to compare programs to the null alternative of no program instead of to the most reasonable alternative programs.(16)

Thus, there must be at least two alternatives, but there is no upper limit to the number of alternatives that must be identified.

Requirement 3. The alternatives must be comparable. The analyst must make sure that the alternatives are comparable, otherwise the results will be of little use. A common mistake is to examine alternatives that serve different target populations and assume that each alternative would have the same costs and effects, regardless of the target populations.

A mobile clinic, for example, might appear less cost-effective than a static MCH clinic. But if the mobile clinic serves a largely rural population and the static clinic an urban population, the target populations would not be the same and the comparison would not be valid. It would be valid to do a CEA to determine whether mobile or static clinics were better for serving one of those populations, say rural people.

> In general, the cost-effectiveness ratio serves as an accurate gauge of relative program desirability only when costs or measures of effectiveness are the same across programs. Then one seeks the least costly program to achieve a given level of effectiveness, or the most effective program given a level of costs.(17)

One way that analysts try to insure comparability is by holding either the numerator (costs) or the denominator (effectiveness) constant for each alternative, as was done in the previous examples. (See tables 1-4 and 1-5.)

Another way to insure comparability is by expressing cost in per capita terms and effects in some standard ratio, such as the number of deaths averted per 100,000 population. In general, analysts can do CEA in one of two ways:

- By holding effectiveness constant (15,000 immunized children), use CEA to identify the least expensive approach; or
- By holding costs constant (a fixed budget of $45,000), use CEA to identify the most effective approach.

In a retrospective CEA, neither costs nor effectiveness may be held constant, in which case the analyst has to estimate costs and effectiveness at set levels. For example, the analyst could either calculate the number of lives that could be saved by each program at the same cost--say $2 million--or calculate what each program would cost to save the same number of lives--say 20,000.

Researchers report that it can be particularly difficult to hold effectiveness constant. As mentioned previously, the target populations may not be comparable. Even when they are, the analyst has to be careful that the services provided to each group are comparable. For instance, a static clinic serving rural children may provide more comprehensive services than a mobile clinic serving the same children, or the quality of care provided by a physician-nurse team may not be the same as that provided by a physician-auxiliary personnel team.

Since, in real life, alternatives seldom are exactly comparable, analysts often have to compromise by trying to make them as comparable as possible and by pointing out to decisionmakers using the CEA results the likely effects caused by the differences. This subject will be discussed later as a limitation of CEA.

Requirement 4. The costs and effects of each alternative must be measured. This may seem to be an obvious requirement, but as will become clear from the discussions in Appendices A and B, it is not always feasible to measure all of the relevant costs and effects. When this occurs, there is a temptation to ignore them and to rely on those items that can be measured. This can be misleading. Thus, the analyst must be careful to identify all of the relevant items to be measured. If some cannot be measured quantitatively, they should at least be measured in qualitative terms and be included in the analysis. This subject is discussed in more detail in the appendices.

LIMITATIONS OF COST-EFFECTIVENESS ANALYSIS

Cost-effectiveness analysis is an analytical tool, and when it is used judiciously, it can be a useful aid in decisionmaking. However, as with other analytical techniques, it has its limitations, and analysts should be cautious both in designing a CEA and in interpreting its results.(18)

The preceding discussion presented the requirements for CEA. In actual practice, however, analysts often are presented with problems when they apply theoretical concepts and methods to real life situations that do not conform to specific needs of research or that may not lend themselves to quantification. These instances require creativity in the research design and judgment on the part of the analyst in interpreting the results. For purposes of this discussion, the limitations of the CEA techniques have been categorized as follows: concepts, measurement, calculation, data, and interpretation.

Conceptual Limitations

A number of conceptual issues have not as yet been satisfactorily resolved by experts in CEA. One of these issues was introduced earlier in the discussion about the need to use exactly comparable alternatives. This issue and others that present conceptual problems important for an analyst to consider are summarized briefly below:

How can an analyst conduct a CEA when alternatives are not exactly comparable? The ideal CEA would have every alternative identical on all criteria except one input or output criterion that could be accurately quantified. In the real world, as Kazanowski said, "such evaluations are relatively infrequent."(19) The analyst should be aware of this limitation and make sure that the alternatives are as comparable as possible. At a

minimum, the differences in the alternatives should be described and assessed in the analysis. If the differences are trivial, they may not affect the overall conclusions. However, if they are significant, they may render the CEA invalid.

How can a CEA be designed when multiple effects are involved? Most CEAs are based on the analysis of a single cost and single effect (e.g., dollars/ immunized child). However, many programs have multiple effects. The Expanded Program on Immunization (EPI), as an example, can include immunization against diptheria, whooping cough, tetanus, tuberculosis, measles, and polio. Primary health care programs are even more comprehensive. As another illustration, a single community health worker (CHW) can provide a broad range of preventive, curative, and rehabilitative services. Thus, a CEA that relies on a single measure of effectiveness may produce an incomplete and misleading conclusion.

Analysts have not come up with an entirely satisfactory answer to this problem. Some attempt to distribute costs and effects by health intervention (X dollars for polio, Y dollars for measles, etc.). Others have tried to develop composite indices of effects; still others look at the interventions one at a time. Some analysts have tried to develop a common denominator for outputs (e.g., number of people served) and impacts (number of deaths averted). Examples of some of these approaches are given in Appendix B. Again, in conducting a CEA, an analyst should, at a minimum, describe multiple effects and undertake qualitative analyses if quantitative analyses are not possible.

Which costs and which effects should be measured? What should and should not be measured in a CEA also is subject to debate. Some analysts believe that all costs and all effects should be measured. Others believe that this is impractical and unnecessary, and advocate measurement of only selected costs and effects--principally, those that vary among alternatives. The issue is particularly complicated when it comes to choosing effectiveness measures. Researchers must consider such issues as "Should the selected measure be an immediate output or a long-term health impact?" And, "Which ones should be measured?" One approach is to select those measures that are relevant to the decision at hand and can be quantified, and at the same time mention other measures that cannot be quantified in a discussion of the CEA findings.

Measurement Limitations

As was mentioned previously, some costs and effects cannot be measured accurately. When quantifying costs, analysts have particular difficulties in determining the value of contributions, estimating future costs of imported items, and predicting the effects of inflation on costs. Appendices A and D discuss these and other issues and provide suggestions to assist analysts in estimating costs. On the effects side, it is very difficult to measure such non-events as births and deaths averted and short-term changes in mortality and morbidity. Even changes in knowledge, attitudes, and behavior are not easy to measure. Thus, many CEAs are based either on assumptions of costs and effects or on substitute measures. Again, those measures that cannot be quantified should be assessed qualitatively by the analyst, and important assumptions should be described.

Calculation Limitations

Cost-effectiveness analysis based on the examination of discrete alternatives (see tables 1-3 through 1-5) has one serious limitation: the optimum alternative may not be among those considered. For example, table 1-4 compared three discrete alternative immunization strategies (campaign, mobile units, MCH clinics). This CEA did not include other alternatives (e.g., physicians, weekend clinics at markets) or a mix of the alternatives. The number of alternatives may be very large, and it may not be practical

to calculate the cost-effectiveness of each one. Some reasonable screening mechanism is usually employed to reduce the alternatives to a manageable number. For problems involving continuous variables, the approach illustrated in figures 1-2 and 1-3 is an effective way to deal with this problem.

Data Limitations

Even if an analyst knows how to measure a particular cost or effect, in some cases the data may not be available, complete, accessible, or valid. A common problem in CEA is the need to make projections of costs and effects when there is no experience from which to draw. For example, how does one estimate the cost of immunizing nomads or the effectiveness of a new radio education program that has not been tried? The analyst may have to make some assumptions, but they can lead to wrong conclusions. Appendix D describes an approach, called Cost-Utility assessment, that can be used in such situations. In any case, the analyst should describe assumptions fully and take them into account when CEA results are used in decisionmaking.

Interpretational Limitations

One of the most important limitations to keep in mind in using CEA results is that this method is only one of several analytical tools available to researchers and decisionmakers. Cost-effectiveness data should be one component--but not the only one--considered in making a final decision. No one would buy a car solely on the basis of a CEA of miles per gallon, although this would be an important criterion. Other criteria such as size, comfort, color, and dependability also would be taken into account. The same holds true for CEAs of primary health care. Other factors, both objective and subjective, will--and should be--considered by the decisionmaker in selecting an alternative. For example, one alternative in a sanitation project--constructing wells--might be preferred by a decisionmaker because it would employ more people, even though it is not as cost-effective as another alternative.

Overgeneralization of CEA results is another danger. Administrators often are tempted to take a CEA and extrapolate beyond the applicability of the data. As an example, an administrator might conclude, "If program A could immunize 15,000 children for $45,000 ($3 each), then could it not immunize 150,000 for $450,000 ($3 x 150,000)?" This reasoning may be valid, but it also may not be, because a larger program might cost more per child immunized. For instance, the additional 100,000 children might be harder to reach, thereby raising costs. The possibility also exists that a large program might be less expensive (e.g., the program might obtain quantity discounts on bulk purchases of vaccines). Again, the alternatives have to be comparable, and in this case, the analyst should do a new CEA of the larger program and not assume that the results can be generalized.

STRENGTHS OF COST-EFFECTIVENESS ANALYSIS

Even with these limitations, CEA can be a powerful tool. Compared to other decisionmaking approaches, such as intuition, presidential decree, and group consensus, it is a much more analytical approach. Also, the process of conducting a CEA can lend discipline to decisionmaking, because CEA provides a framework for organizing and examining information in a systematic manner. It also helps clarify how decisions are made, since it requires that decisionmakers specify and clarify their values. As an analytical method, this technique is generalizable and flexible. It can be used at various levels of precision and sophistication to assist decisionmakers in finding solutions to an unlimited range of problems.

The following chapter presents a step-by-step guide to conducting a CEA.

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CHAPTER II

STEPS IN COST-EFFECTIVENESS ANALYSIS

CHAPTER II. STEPS IN COST-EFFECTIVENESS ANALYSIS

Cost-effectiveness analysis is a six-step process. As shown in figure 2-1, the steps include the following tasks.

1. Define the operational problem and objectives.
2. Identify the alternative solutions to the problem.
3. Identify and measure the costs of each alternative.
4. Identify and measure the effectiveness of each alternative.
5. Analyze the costs, effectiveness, and cost-effectiveness of each alternative.
6. Conduct a sensitivity analysis.

These steps will be described in the following pages, and each step in the process will be illustrated with a case example. More detailed descriptions of methods for applying CEA to other types of problems are contained in the appendices.

STEP 1: DEFINE THE OPERATIONAL PROBLEM AND OBJECTIVES

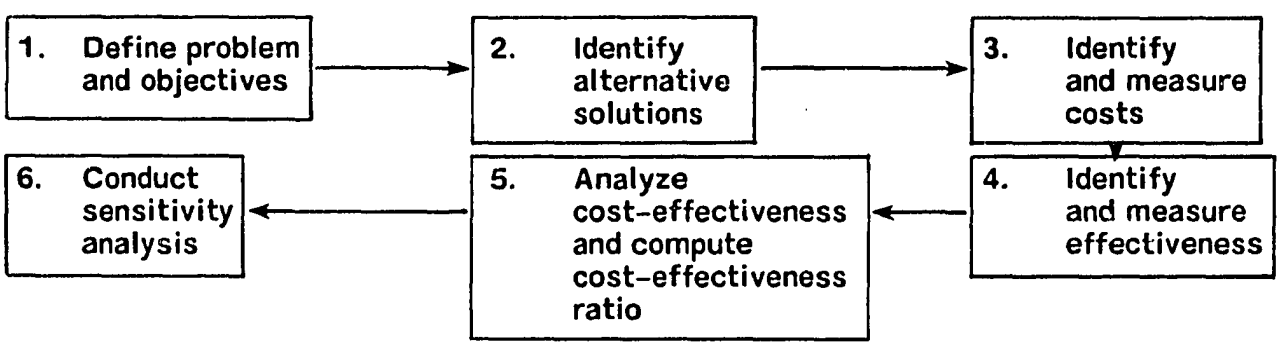
Before devising a solution to an operational problem, the analyst and decisionmaker first must understand the problem clearly. Problem analysis usually begins with the identification of a discrepancy between what should be happening and what actually is occurring. For example, villagers should be supporting their health workers, but they are not; or, oral rehydration salts were to be readily available to rural populations, but they are not. The general problem should then be analyzed in detail to define its scope, magnitude, seriousness, characteristics, and probable causes.

Once the problem has been identified, the analyst and decisionmaker need to set their objectives. As explained by Quade, a specialist in decision analysis:

> A person must first determine his goals or objectives--what it is he wants to accomplish--so that he can search out the various alternatives or possible means of attaining what he wants.(1)

It is helpful to identify the characteristics of the desired solution in quantitative terms. For example, if the problem is that not enough children are being immunized, the objective might be stated as follows: to immunize (number) children aged 1-5 against (diseases) in (provinces) by (date). In operations research terminology, such statements of the characteristics of the desired solution are called objective functions.

Figure 2-1.--Steps in Cost-Effectiveness Analysis



Case Example: Step 1

The Ministry of Health (MOH) of a Caribbean country administers a primary health care program that has stalled, in part, because a large number of promotors (community health workers) have not been trained. Each promotor is supposed to receive 3 weeks of basic health training in groups of 15-30 in a rural clinic near their homes. They also are to receive an additional week of training at a regional nutrition center. Actually, the training lasts only 2 weeks, and more than 700 promotors (60 percent of the total) have received no training at all. The current training is based on a hierarchical strategy in which central office trainers instruct regional trainers who train district supervisors. These supervisors then train nurses to train the promotors. This system not only has failed to train adequate numbers of promotors, but the quality of training has been poor.

The decisionmakers at the MOH want to try an approach using a core staff of trainers and audiovisual materials. This approach has proved to be very successful in training census workers. Experience has shown that it is a fast and effective method.

A study is planned to find the most cost-effective way to adapt this method to the training of promotors in two health interventions: oral rehydration therapy and malaria prophylaxis. A research team is formed. It includes the principal investigator, who is a sociologist by training; an economist; and a research assistant. Working with MOH trainers, the team will identify training alternatives for the CEA, and then analyze each alternative in terms of its probable costs, effectiveness, and cost-effectiveness. The most desirable of the alternatives will then be implemented nationwide.

STEP 2: IDENTIFY THE ALTERNATIVE SOLUTIONS TO THE PROBLEM

In some cases, the alternatives to be used in the CEA are fairly obvious or can be identified relatively simply through a review of the literature or by means of a group discussion. At other times, identification of the alternatives may be more complex, and require such tasks as development of consensus among a group, conduct of a systems analysis, or construction of a mathematical model.

The PRICOR monograph, Operations Research Methods: A General Approach in Primary Health Care, describes a number of approaches that can be used to identify alternatives.

Case Example: Step 2

Although the MOH has decided on a general training approach, the actual structure of that approach has not been determined. As the next step in a CEA to assist decisionmakers, the research team and MOH trainers select eight decision variables for each course (ORT and malaria prophylaxis) that can be manipulated to identify the most cost-effective system. The variables include:

1. Training content
2. Training methods
3. Training materials
4. Trainers
5. Duration of training
6. Class size
7. Training location
8. Level of supervision following training.

For purposes of the study, the research team and trainers plan to standardize variables 1, 2, and 3 (the training content, methods, and materials) based on an assessment of promotor training needs and past experience. They also determine that the training can be completed in 1 day (variable 5), and that for budgetary reasons, training classes will be held at district offices. The team determines that there are relatively discrete options for the remaining variables:

- Trainers--regional staff or district staff (variable 4)
- Class size--20 or 40 promotors per class (variable 6)
- Supervision--monthly or semi-annual supervisory visits (variable 8).

In the CEA, different combinations of these variables will be compared for the two training courses. (See table 2-1.) This study design produces a total of 16 alternatives that will be examined in terms of their anticipated costs, effectiveness, and cost-effectiveness ratios.

STEP 3: IDENTIFY AND MEASURE THE COSTS OF EACH ALTERNATIVE

Before the costs can be measured, the analyst and decisionmaker have to determine which costs to measure. Quade suggests concentrating only on those costs relevant to the decision.

> All costs are relevant to some decision or other. The responsibility of the cost analyst, however, is not simply to add up any and all costs indiscriminately, but to identify and measure that particular collection of costs contingent on the specific decision or choice under consideration. To do that he must distinguish the relevant from the irrelevant ones. . . . Relevant costs are those that depend on the choice made, given the choices available.(2)

Table 2-1.--Alternative Combinations of Decision Variables in Case Example

ALTERNATIVES			MALARIA			ORT		
Trainers	Class size	Supervision	C	E	CE*	C	E	CE*
Regional	20	monthly						
Regional	20	semi-annual						
Regional	40	monthly						
Regional	40	semi-annual						
District	20	monthly						
District	20	semi-annual						
District	40	monthly						
District	40	semi-annual						

= costs; E = effectiveness; CE = cost-effectiveness

Table 2-2.--Illustration of Common and Variable Costs

COSTS CATEGORIES	ALTERNATIVES A	B	C
Common costs			
Facilities	3,000	3,000	3,000
Equipment	600	600	600
Utilities	150	150	150
Supplies	250	250	250
Variable costs			
Personnel	1,200	1,800	1,500
Travel	1,200	2,300	2,800
Per diem	1,600	2,800	3,400
Communications	2,500	900	300
Total costs	10,500	11,800	12,000
Less common costs	4,000	4,000	4,000
Variable costs	6,500	7,800	8,000

Quade's point can be illustrated with an example. If alternative training programs have the same costs for facilities, equipment, utilities, and supplies, but different costs for personnel, travel, per diem, and communications, then the latter set makes up the relevant costs. They will vary with each alternative. Because the first group of costs are the same for each alternative, they will cancel each other out. The ranking of alternatives will be the same, whether these common costs are included or excluded; however, the actual cost-effectiveness ratio will be different, depending on whether the common costs are included or not. Table 2-2 provides a helpful example of how costs may be calculated.

One way to make sure that all the relevant costs are identified is to describe the "production function" of each alternative; i.e., the process by which resources are turned into outputs. A simple flowchart that describes the activities of the process is useful for this purpose. Using such a chart, the activities for which costs must be computed are identified. For example, the key steps in a training alternative might be those shown in figure 2-2. The total costs for this program would be computed by listing the relevant cost categories for each step shown in the figure.

Figure 2-2.--Illustration of Key Steps of a Training Program

Assessment of training needs → Development of training curriculum → Delivery of training → Evaluation of training

Table 2-3.--Worksheet for Identifying Relevant Costs of Training Alternatives

	KEY STEPS IN TRAINING				
	Assess needs	Develop curriculum	Deliver training	Evaluate training	Total costs
RECURRENT COSTS					
-Personnel					
-Fringe benefits					
-Consultants					
-Materials/Supplies					
-Travel/Transport					
-Other					
-Communications					
-Contract services					
-Miscellaneous					
CAPITAL COSTS					
-Land					
-Buildings					
-Equipment					
TOTAL					

Costs usually are classified as direct or indirect, capital or recurrent, fixed or variable, and average or marginal. These distinctions, which are described in more detail in Appendix A, can be useful when trying to identify the relevant costs to measure. One way to categorize common costs is shown on the left column of table 2-3 and described briefly below.

- Recurrent Costs

  - Personnel: Salaries and wages of both full-time and part-time staff assigned to a project. Includes expenses for overtime, bonuses, and commissions; also includes the monetized value of donated time of volunteers.

  - Fringe benefits: Holiday and vacation pay, year-end bonuses, sick and administrative leave, and all other similar compensation; health and life insurance; pension and social security contributions; accident compensation; uniform, housing, and transportation allowances; and similar benefits. Sometimes these benefits are included in personnel costs and do not need to be computed separately.

  - Consultants: Fees or honoraria for short-term services of experts, advisers, and others who are not employees.

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- Materials and supplies: Consumable commodities, the most important of which are drugs, medications, medical supplies, and health kits, as well as office supplies, books, and educational materials. Includes supplies purchased directly by the program and those which are donated or subsidized.

- Travel and transportation: Air and ground travel of staff and consultants, meal allowance (or per diem), transportation of equipment and materials, shipping charges of equipment and materials, and costs of operating and maintaining vehicles, including gasoline.

- Other direct costs: Includes three principal categories: 1) communications--telephone, telegraph, postage; 2) contract services and other professional services for which contracts are negotiated; and 3) miscellaneous costs--printing, reproduction (making copies), membership and dues, utilities (water, electricity, etc.).

- Capital Costs

  - Land: Purchased or donated land for clinics, housing, garages, etc.

  - Buildings: Health huts, clinics, hospitals, offices, staff houses, garages, warehouses, etc.

  - Equipment: Vehicles, medical equipment (X-ray machines, centrifuges, beds), office data processing and audio-visual equipment, spare parts.

Once the cost categories, or "ingredients," have been identified, the monetary value of each ingredient has to be computed. For a prospective CEA in which the effects are held constant, the analyst would have to calculate what each alternative would cost to achieve the given level of effectiveness. If costs were held constant, the analyst would calculate the amount of output each alternative would produce for the given level of cost. In a retrospective CEA, the analyst usually would be working with available expenditure data and would calculate the actual costs of each alternative.

In computing costs, the analyst has to understand how to discount capital costs, make adjustments for inflation, estimate the value of in-kind contributions, and make other adjustments to produce an accurate estimate of the true cost of each alternative. These procedures are described in Appendices A and D.

Case Example: Step 3

Continuing with the case example discussed above, the economist on the research team sets about identifying the relevant costs and collecting the data needed to cost out each alternative. Since each of the country's 1,170 promotors will be trained in the two courses (ORT and malaria), the economist holds that output (i.e., 1,170 promotors) constant for each alternative. Thus, for each of the eight ORT training alternatives, she calculates the cost of training 1,170 promotors. In discussions with the MOH trainers, she determines that some costs will be constant for each alternative (e.g., the development of the training curriculum). Further, she decides to measure only those costs which will vary with each alternative. Costs which in her analysis are assumed to be constant are:

3V

- Personnel

  - Trainee (promotor) opportunity costs (the value of services not performed while attending training)
  - MOH central staff-time spent developing training program

- Materials

  - ORT packets and malaria prophylaxis used in training

- Travel

  - Trainee travel and subsistence costs from home to training site

Costs that will vary with each alternative are:

- Personnel

  - Trainer salaries and fringe benefits
  - Supervisor salaries and fringe benefits during post-training supervision
  - Central office staff salaries and fringe benefits during training

- Materials

  - Training materials and supplies

- Travel

  - Travel and per diem of trainers during training
  - Travel and per diem of supervisors during post-training supervision
  - Travel and per diem of central office staff during training

- Capital costs

  - All equipment, vehicles, buildings (discounted)

- Other direct costs

  - Communications--telephone, postage
  - Contract services--cleaning of training sites, rent of facilities and equipment, utilities (water, electricity, fuel for heat)
  - Miscellaneous--printing, making copies, messenger services.

The economist believes that opportunity costs may be very important and should be included in the analysis, even if they cannot be quantified. For example, if a regional nurse has to spend 14 days training promotors, the value of what she could have done instead (e.g., provided service to 200 patients, supervised 40 promotors, etc.) is part of the total cost of the training program.

The economist next traces the steps in the production function and finds that there are some differences among the training program alternatives being considered. For example, if district staff were used as trainers, the central office staff would have to conduct more train-the-trainer courses than if regional staff were used. Also, more

materials and more travel would be needed. She describes the production functions and then collects the data needed to cost out each alternative.

STEP 4: IDENTIFY AND MEASURE THE EFFECTIVENESS OF EACH ALTERNATIVE

The analyst must now decide how to measure the CEA objective. This process involves two interrelated steps:

1. Deciding which outcome criteria to use, and
2. Developing specific measures for those criteria.

A criterion is a characteristic, rule, or test used to make a judgment about an alternative (e.g., a successfully immunized child). A measure is a number assigned to that criterion (e.g., the percentage of children within the target population successfully immunized).

It is useful to think of outcomes as falling along a continuum from the immediate (short-term) effects to the ultimate (long-range) impacts, as shown in table 2-4. This classification helps the analyst and decisionmaker visualize where a particular criterion of effectiveness might fall along the cause-effect chain. In general, it usually is easier to measure immediate outputs than long-term impacts, but these measures may not be adequate for certain decisions. Impacts are usually more desirable as criteria, but they also are more difficult to measure. However, in some cases, such as immunization against measles, the immediate effect (children immunized) may be sufficient as a criterion of effectiveness, since the ultimate health impact of measles immunization is well known.

For two reasons, most CEAs in primary health care measure the immediate service outputs and effects rather than long-range health impacts. First, CEAs in primary health care usually are concerned either with finding better ways to deliver goods and services or with effecting changes in a target population's knowledge, attitudes, and behavior rather than determining the health impact of interventions. Second, health impacts are difficult to measure, often requiring long-term experimental research designs. Cost-effectiveness analyses, on the other hand, usually are designed to respond to immediate operational

Table 2-4.--Classification of Outcomes on Cause-Effect Chain

		OUTCOMES		
INPUTS →	PROCESSES →	OUTPUTS →	EFFECTS →	IMPACTS
		Immediate goods and services provided	Immediate effects on target population: - Knowledge - Attitudes - Behavior	Long-term Impact on target population: - Health - Socioeconomic status
Example:		ORS packets distributed	Mothers use ORS packets	Infant mortality declines

decisions facing host country policymakers and program managers. Nevertheless, some analysts may need to measure health impacts. For that reason, some of the most common of criteria used to measure impacts are listed in table 2-5, with some of the most common output and effect criteria. A more detailed list can be found in Appendix B.

Once the general criteria of effectiveness have been selected, they should be defined more specifically. Since most primary health care programs are directed at specific target populations, the characteristics of that population should be defined. A minimum definition includes the sex and location of the target population (e.g., "immunization of all children aged 1-5 years in the rural sections of Gualapa Province"). Including a precise description is important to insure that the outcomes being measured are the same for each alternative under consideration. As mentioned in chapter I, if one alternative is aimed at urban children and another at rural children, they are not comparable, and a CEA using such alternatives would be misleading. This and other relevant measurement issues are discussed in more detail in Appendix B.

After the specific effectiveness criteria for a CEA have been defined, the measures to be used can be identified. (See table 2-6 for examples.) Measures can be counts, ratios, proportions, or percentages. Although any of these can be used in a CEA, most analysts use counts or percentages. Appendix B provides a more detailed description of the procedures for developing measures of effectiveness.

Once the effectiveness measures have been selected, their values have to be computed. Again, as with the calculation of costs, the procedures will differ slightly depending on whether the CEA is prospective or retrospective and whether costs or effectiveness are held constant.

Table 2-5.--Selected Criteria for Assessing the Effectiveness of Primary Health Care Programs

OUTPUTS	EFFECTS	IMPACTS
Contacts made	Enrollees	Infant mortality
Visits made	Active users	Child mortality
Referrals made	Dropouts	Neonatal mortality
Appointments	Households using ORS	Perinatal mortality
Individuals served	Households using growth charts	Fetal mortality
Households served	Children immunized	Weight at birth
Examinations given	Malaria prophylaxis	Height for weight
Cases treated	Family planning acceptors	Incidence of (disease)
Education sessions held	Wells constructed	Maternal mortality
Units of commodity distributed	Latrines constructed	Crude birth rate
	Pregnant women receiving prenatal care	
	Supervised deliveries	

Table 2-6.--Examples of Effectiveness Measures

CRITERIA		MEASURES (Counts)	(Percentages)
OUTPUT	Screening visits made by CHW	Number of CHW visits to households with children aged 1-3	Percentage of households with children aged 1-3 visited by CHW
EFFECT	Households using ORS	Number of households using ORS	Percentage of households using ORS salts
IMPACT	Deaths from diarrhea	Number of deaths of children aged 1-3 from diarrhea	Percentage of children aged 1-3 dying from diarrhea

Case Example: Step 4 of a Sample CEA

While the economist is calculating the costs of the training alternatives, the principal investigator works on the development of effectiveness measures. Although the ultimate objective of the training is to reduce mortality and morbidity, the team determines that it would be impossible to measure any significant change in the short time available for the research project. Thus, the more immediate concern of the Minister--training the promotors to provide needed services--is selected as the effectiveness measure. Working with the MOH trainers, the team selects the effectiveness measures shown in table 2-7.

Most of these data will be collected and analyzed during the field test of the selected training alternative. During the prospective stage of the study, the research team will have to rely on two measures: the estimated percent of all promotors that will have to be trained and the estimated percentage of the trainees that will pass a knowledge and skills test at the end of training. Estimates for these two measures can be obtained from experience with current training programs and from the recent experience with the new training method among census workers. No data are available that would permit estimating the effects training is likely to have on promotor behavior or on parents. Thus, the team makes estimates of effectiveness for each of the 16 alternatives as shown below:

Immediate output $\frac{\text{Number of promotors expected to complete training}}{\text{Total number of promotors (1,170)}}$

Immediate effects $\frac{\text{Number of promotors expected to pass a knowledge skill test}}{\text{Total number of promotors (1,170)}}$

Table 2-7.--Case Example of CEA Effectiveness Criteria

	ORT TRAINING	MALARIA PROPHYLAXIS TRAINING
Training Outputs	Promotors trained	Promotors trained
EFFECTS on Promotors:		
Knowledge	Trainees who understand: Symptoms How to prepare solution How to follow treatment protocol	Trainees who understand: Symptoms How to administer tablets How to follow treatment and prevention protocols
Skills	Trainees who can: Prepare ORT solution Prepare salt-sugar solution	Trainees who can: Diagnose malaria Follow treatment and prevention protocols
Behavior	Households contacted Cases identified Cases referred Cases supervised Households supplied with ORS	Households contacted Cases diagnosed Cases referred Cases supervised Households supplied with tablets
EFFECTS on Parents:		
Knowledge	Parents who understand: Symptoms How to prepare solution How to follow treatment	Parents who understand: Symptoms How to administer ORS Prevention protocol
Skills	Parents who can: Prepare ORS solution Prepare salt-sugar solution	Parents who can: Diagnose malaria Follow treatment protocol
Behavior	Those using ORT: At onset of diarrhea During course of diarrhea	Those using malaria prophylaxis: At onset of fever As preventive measure correctly
Health IMPACT		
Mortality	Not recommended as CEA criterion	Not recommended as CEA criterion
Morbidity	Not recommended as CEA criterion	Not recommended as CEA criterion

STEP 5: ANALYZE THE COSTS, EFFECTIVENESS, AND COST-EFFECTIVENESS OF EACH ALTERNATIVE

Once the data have been collected and tabulated, the data analysis begins with an examination of the costs of each alternative. Four cost analysis procedures are described in detail in Appendix C. They are:

1. How to compare the magnitudes of the costs (i.e., which is the most and least costly alternative).

2. The percent distribution of the line items of each alternative (e.g., personnel = 55 percent of the costs, transportation = 25 percent).

3. The absolute difference in costs by line item (e.g., personnel costs of Alternative A are $3,500 more than those of Alternative B).

4. The relative differences in line item costs (e.g., personnel costs of Alternative A are 34 percent higher than those of Alternative B).

Analysis of total costs and line item costs can provide a complete description of both the actual and relative costs of each alternative and its components. This type of information would be particularly useful in explaining why one alternative is more or less expensive than another and for identifying areas where costs might be reduced.

The analysis of effectiveness can also include examination of:

1. Differences in the magnitudes of each alternative.

2. The absolute differences in outcomes.

3. The relative differences in outcomes.

These topics also are described in more detail in Appendix C.

Finally, the cost-effectiveness ratio can be computed by dividing the total cost of each alternative by its outcome data. Appendix C also describes this procedure.

Case Example: Step 5

The research team examines the cost data for each alternative (see table 2-8 for the data on the ORT training) and determines that the fourth option (regional trainers, classes of 40, semi-annual supervisory visits) would be the least costly for both the ORT and malaria courses. An examination of the line items indicates that this alternative would be cheaper than the others because it would provide significant savings in personnel and travel costs. The most expensive alternative would be the fifth (district trainers, classes of 20, monthly supervision), because it would involve more personnel and travel costs.

Examining the effectiveness estimates, the team finds that the alternatives that are likely to train the greatest number of promotors are the small classes held at the district level (Alternatives 5 and 6). Experience has shown that attendance is higher at the district level, because the site is closer to the promotors' communities and the attendees know one another. The data also show intensity of supervision has no effect on attendance at training, but it does affect learning. The alternatives that include more

Table 2-8.--Summary of Cost and Effectiveness Data for ORT Training Alternatives in Case Example

Alternative (Trainers/students/ supervision)	Total costs (US$)	Percentage of all promotors trained (N= 1,170)	Percent of promotors trained who pass test
1. Reg/20/mo*	67,250	87 (1,018)	90 (916)
2. Reg/20/sa**	58,950	87 (1,018)	85 (865)
3. Reg/40/mo	48,975	83 (971)	87 (845)
4. Reg/40/sa	44,350	83 (971)	83 (806)
5. Dist/20/mo	72,250	95 (1,111)	87 (967)
6. Dist/20/sa	61,800	95 (1,111)	83 (922)
7. Dist/40/mo	54,280	90 1,053)	85 (895)
8. Dist/40/sa	52,470	90 (1,053)	80 (842)

* mo = monthly; **sa = semi-annually

intensive monthly supervision are known to result in more learning, because continuing education is provided by the supervisor. Learning also is greater in smaller classes, and in those conducted by the regional staff, who are known to be more effective trainers. Thus, the most effective alternative, in terms of learning, is expected to be number 1.

The research team next examines the cost-effectiveness ratios for each alternative. Ratios are calculated for both measures of effectiveness by dividing the costs by the number of promotors expected to be trained and also by the number of promotors expected to pass the test. A sample of the team's calculations for ORT training is shown in table 2-9.

Table 2-9.--Cost-Effectiveness Ratios for ORT Training Alternatives

Alternative (Trainers/students/ supervision)	Cost/Promotor Trained (US$)	Cost/Promotor Passing Test (US$)
1. Reg/20/mo*	66.06	73.42
2. Reg/20/sa**	57.91	68.15
3. Reg/40/mo	50.43	57.96
4. Reg/40/sa	45.67	55.02
5. Dist/20/mo	65.03	74.72
6. Dist/20/sa	55.62	67.03
7. Dist/40/mo	51.55	60.65
8. Dist/40/sa	49.83	62.32

*mo = monthly; **sa = semi-annually

Calculations show that for both malaria and ORT training, the most cost-effective alternative on both measures is number 4. Alternative 3 appears to be the second most cost-effective of the eight considered in the CEA.

After examining all of the data on costs, effectiveness, and the cost-effectiveness ratios, the research team recommends the fourth alternative. Although not the most effective, it is the least costly, and it appears to be the most cost-effective of the eight. However, the team decides to rank the alternatives in order and present the summary data to the MOH trainers and the Ministry for consideration. Their ranking of the alternatives for ORT training is shown in table 2-10.

STEP 6: CONDUCT A SENSITIVITY ANALYSIS

The results of a CEA are very dependent on the assumptions used in estimating costs and outcomes. Before making a categorical recommendation to accept an alternative, analysts should test whether variations in those assumptions would change their conclusions. One way to do this is through sensitivity analysis. As Shepard and Thompson explained, sensitivity analysis is

> . . . the process of deliberately varying these uncertain factors to examine their effect on the decision rule. If the final decision is not affected by making different assumptions about these uncertain quantities--by choosing high and low estimates, for example--then one can be relatively confident of the decision. If, on the other hand, the decision would be drastically altered by different estimates, then one should be considerably more cautious in making recommendations.(3)

In conducting a sensitivity analysis, a researcher identifies the significant assumptions and varies them. For example, the analyst might need to consider whether a change in the discount rate would affect the conclusion (e.g., if the rate of interest were 20 percent instead of 10 percent, would this change the cost of the alternatives

Table 2-10.--Ranking of Eight ORT Training Alternatives in Case Example

Rank Order	Alternative	Cost	Number trained	No. passing test	Cost/No. trained	Cost/No. passing test
1	4. Reg/40/sa*	44,350	971	806	45.67	55.02
2	3. Reg/40/mo**	48,975	971	845	50.43	57.96
3	8. Dist/40/sa	52,470	1,053	842	49.83	62.32
4	7. Dist/40/mo	54,280	1,053	895	51.55	60.65
5	2. Reg/20/sa	58,950	1,018	865	57.91	68.15
6	6. Dist/20/sa	61,800	1,111	922	55.62	67.03
7	1. Reg/20/mo	67,250	1,018	916	66.06	73.42
8	5. Dist/20/mo	72,250	1,111	842	65.03	74.72

*sa = semi-annually; **mo = monthly

significantly?). As another example, prices of certain key primary health care budget items are so volatile and unpredictable that, as a general rule, they should probably be subjected to sensitivity analysis. Among these items are costs of personnel (particularly CHW salaries), fuel, drugs, medical equipment, and vehicles.

Outcomes also should be subjected to sensitivity analysis. Prime candidates are those outcomes that have to be measured indirectly or estimated, such as births and deaths averted, morbidity, active cases, continuing users, dropouts, and referral appointments kept.

If a sensitivity analysis indicates that some variables are sensitive to changes in the assumptions, then there are two principal courses of action that may be taken: either the researcher can try to collect more accurate data to reduce uncertainty, or the decisionmaker can decide among the alternatives by examining the assumptions and deciding which seem to be the most reasonable.

Case Example: Step 6

The research team and MOH trainers conduct a sensitivity analysis, varying the assumptions about costs and effectiveness. They are confident about the cost data and do not think that variations in their assumptions make much difference in the relative ranking of the alternatives. However, they are not sure of their assumptions about learning--particularly about the effect of more intensive supervision and the ability of the regional staff to carry out additional monthly supervisory visits. After discussing these options with the Minister, they determine that a new alternative should be examined: training classes of 40 students with monthly supervision by district staff. The research team computes the costs, expected effectiveness, and cost-effectiveness of this alternative and presents the new data to the Minister. They agree to test this approach and Alternative 4.

After the field test is conducted, the research team will calculate the actual costs, effectiveness, and cost-effectiveness ratios of the two alternatives.

A FINAL NOTE

As the case example illustrates, CEA can be a useful tool for decisionmaking if applied judiciously and if its limitations are understood and accepted. The appendices that follow provide more detailed explanations of how to compute costs and effectiveness, analyze the resulting data, and deal with a number of the issues raised in these first two chapters.

NOTES

. E.S. Quade, Analysis for Public Decisions, second edition, (New York: Elsevier Science Publishing Co., 1982), p. 31.

. Ibid., p. 123.

. Donald S. Shepard and Mark S. Thompson, "First Principles of Cost-Effectiveness Analysis in Health," Public Health Reports, November-December, 1979, p. 539.

APPENDIX A

A GUIDE TO CALCULATING COSTS

APPENDIX A. A GUIDE TO CALCULATING COSTS

This appendix defines and illustrates the basic cost concepts that are needed to calculate the costs to be considered in a cost-effectiveness analysis. Specifically, the sections that follow describe:

- Types of costs (direct and indirect, capital and recurrent, fixed and variable, average and marginal)
- Monetary and nonmonetary cost calculations.
- How to calculate recurrent and capital costs.

Illustrative worksheets in this appendix serve as a framework for organizing the cost calculations. Researchers can readily adapt them to particular projects.

Appendix D presents additional concepts that, in some instances, will be useful in calculating costs with respect to the particular program or question being analyzed. The concepts include: economies of scale, shadow pricing, multiple outputs, foreign exchange costs, inflation, and net analysis.

TYPES OF COSTS

The true cost of a primary health care program is measured as the value that could be gained by using the resources in some other way, such as the building of a surgical unit, the implementing of a nutritional program, or the refurbishing of a hospital.

The first step in cost calculation is to identify all the resources that have been or will be expended to produce the given effect. Whether or not these resources have a monetary or nonmonetary value associated with them is immaterial in this identification phase. (In a later section, guidelines for valuing nonmonetary resources will be given.)

Direct, Indirect, and Infrastructure Costs

The first way to classify costs is as direct, indirect, or infrastructure. Direct costs are directly attributable to the service. For example, the direct costs of expanding a primary health care program to include an ORT component may consist of personnel salaries, volunteer time, ORT salt packets, and transportation. Indirect costs are the costs of supporting the direct services. The expansion of the primary health care program may require the Ministry of Health to hire an additional planner to deal with the administration of the ORT activity, or the Ministry of Transportation may need to hire additional mechanics to service the program's new vehicles. Infrastructure costs are even less directly related to the program. They include the costs of roads, ports, and telephone systems that the program requires.

Capital and Recurrent Costs

Once costs have been categorized as direct, indirect, or infrastructure, they can be classified as capital (or developmental) and recurrent (or operating). The distinction between the two types is based on life expectancy. Those resources that have a life expectancy of 1 year or more usually are called capital costs. They may include buildings, cars, trucks, beds, and medical equipment. Those resources that are purchased and used (or replaced) within 1 year's time are recurrent costs. They include such items as personnel salaries, medicine and supplies, gasoline, electricity, drugs, and food.

The distinction between capital and recurrent costs is important in primary health care CEAs because:

1. These costs are calculated in different ways. (This will be described in a later section.)

2. Some donors limit their contributions to capital costs and expect the host country to be responsible for the recurrent costs.

3. In many countries there is one budgeting and accounting process for recurrent costs and another for capital costs.

Fixed and Variable Costs

Fixed costs do not vary with program size; variable costs do. Examples of fixed costs are those of a building, salaries of permanent staff, and medical equipment. These costs are set (fixed), regardless of whether the program serves 1 person or 1,000. Variable costs include drugs, gasoline, and vehicle maintenance. These items vary with the amount of service provided. The cost of providing ORT packets is an example. The more people served, the greater the number of ORT packets distributed and the greater the resultant cost.

This distinction is particularly important when CEA is used to estimate the costs and effects of expanding a program. Sometimes a program could be expanded inexpensively because the fixed costs would remain the same and only the variable costs would increase. For example, a primary health care program with an ORT component might be expanded from 1,000 to 1,200 persons simply by providing additional oral rehydration packets and some gasoline for the supervisors to deliver the ORT packets to the CHWs. The cost of expansion would be relatively low.

Under another alternative, expansion might require increased fixed costs. For example, new staff and a jeep to serve the additional 200 people, which could increase the cost of expansion significantly. Thus, in designing a CEA it is important to identify and measure those costs that will vary, including the costs of supervision, information systems, storage, and vehicle maintenance.

Average and Marginal Costs

One other distinction in calculating costs is worth mentioning at this point. The average (or per unit) cost is the total cost of a program divided by the total number of units of outcome. An example would be the total cost of an immunization component of a primary health care program (e.g., $10,000) divided by the number of children immunized (e.g., 5,000), which would produce an average cost per child immunized ($2).

A marginal cost is the increased cost of providing an additional unit of outcome. For example, if primary health care Alternative A could immunize 5,000 children at a total cost of $10,000, any additional cost of immunizing the 5,001st child (e.g., $ .40) would be the marginal cost. Hence, marginal costs are the additional resources required for immunizing an additional child. In this case, the expansion--even to one more person--would include the extra vaccine, additional medical supplies, and the amount of personnel time spent in administering the vaccine. The marginal cost calculation is particularly useful when estimating the cost of expanding a program to different levels. Appendix D will deal with marginal cost analysis in more detail.

CALCULATING COSTS

This section describes procedures commonly used to calculate the most common direct capital and recurrent costs. It also includes worksheets and examples. The examples are merely illustrative, and the worksheets can be adapted to fit any program's requirements.

Defining the Production Function

Chapter II quoted Quade's suggestion that the analyst identify and calculate only those costs that are relevant to the decision being considered. But how does one identify the relevant costs? Warner and Luce offer the following suggestion.

> It is crucial that the analyst begin cost analysis by identifying the actual input used and, where possible, their quantities. In essence, this should be reflected in a well-specified production function. There is a temptation, yielded to frequently, to skip this step and use available data on the costs or charges for relevant services.(1)

In addition to identifying the relevant inputs, it can be helpful to describe how they are transformed into outputs--i.e., how the outputs are produced. As discussed in chapter II, developing a simple flowchart of the principal steps in the process is one way to describe the production function. For most primary health care programs, this would involve identifying the program components, activities, or tasks that constitute the alternative and then identifying the quantities of resources that go into each. Table A-1 illustrates a breakdown of program components from the Danfa project. This table shows that the project consisted of three principal components: health center services, satellite clinic services, and community-based programs. Each of these can be further subdivided. For example, community-based programs consisted of seven activities.

Table A-1.--The Danfa Project: Principal Components

PHC PROGRAM COMPONENTS	COMMUNITY-BASED PROGRAM COMPONENTS	NUTRITION COMPONENT ACTIVITIES
Health center services Satellite clinics Community-based programs—	Health education Nutrition —— Sanitation Training traditional birth attendants Expanded immunization Village Health Workers Malaria prophylaxis	Prevention High-risk screening Growth monitoring Rehabilitation

Source: The Danfa Comprehensive Rural Health and Family Planning Project Final Report, University of Ghana Medical School, Accra and UCLA School of Public Health, Los Angeles, September 1978, pp. 613-614.

One of these activities, nutrition services, can be broken down into four major functions: Prevention, high-risk screening, growth monitoring, and rehabilitation. If the CEA were to examine alternative nutrition activities these would be the four "production" activities. Costs would be calculated for each activity to determine the overall cost of the nutrition component. That procedure is illustrated in table A-2, which shows a matrix of the nutrition activities along the horizontal axis, and principal cost categories along the vertical axis. These cost categories were described in chapter II. In conducting a CEA, the analyst would identify the inputs (personnel, consultants, travel, buildings, etc.) for each activity, compute the costs of each, and then sum the total cost of this component.

Monetary and Nonmonetary Cost Estimates and Shadow Pricing

Once the cost categories have been listed for each program, activity, service, or task to be costed, the quantity of each of these inputs must be identified; i.e., the number of hours or days of personnel time, the physical quantities of supplies, the hours of use of facilities. Conversion of these inputs into some monetary unit (e.g., pesos, rupees, dollars) is a critical step in CEA. Many items are easily convertible to a monetary value by using the current market price for the item. For example, personnel costs of health education activities can be computed using current wage and salary rates. However, sometimes this market price does not reflect the true cost of the input, and "uncritical use of market prices can lead to large gaps between cost estimates and the true costs."(2)

Table A-2.--Worksheet for Identifying Relevant Costs

	PRINCIPAL ACTIVITIES OR TASKS (Danfa Nutrition Component)				
COST CATEGORIES	Prevention	Screening	Growth Monitoring	Rehabilitation	Total
RECURRENT COSTS					
Personnel					
Fringe Benefits					
Consultants					
Materials/Supplies					
Travel/Transportation					
Other					
- Communications					
- Contract Services					
- Miscellaneous					
CAPITAL COSTS					
Land					
Buildings					
Equipment					

Sometimes the prices of goods and services are artificially high, low, or nonexistent. Common examples of this phenomenon are the following:

- "Free" drugs and medical care
- Donations for drugs or medical care
- Donations of land, labor, or furniture
- Volunteers, especially community health workers.

For items such as the above, shadow prices should be calculated. Shadow prices are estimates of the true costs of goods or services. For instance, how should the value of a volunteer's time or of furniture donated to a health project be computed? The easiest method would be to assume that the costs are zero since the project paid nothing for them. In fact, this is incorrect. The social cost of these items is not zero, because if the health project had not used them, they could have been used elsewhere. The true cost of these items, their shadow prices, can be calculated in one of two ways.

1. If the project includes similar materials or services that have been purchased in the market, apply these prices to the donated materials or services.

2. If no value can be assigned in this way, calculate the monetary value that would have been paid for the material or service in an alternative project.

For example, if paid employees perform tasks similar to those carried out by volunteers, then a wage rate of the paid employee can be assigned to the volunteer. Otherwise, the analyst should calculate what it would cost to substitute wage labor for the volunteer. The value of donated furniture should similarly be calculated. If no monetary figure is forthcoming, then use the market price for similar furniture.

Great care must be taken at this stage of the analysis, lest artificial inflation or deflation of the program's total cost result from uninformed estimates. Sensitivity analysis (see Appendix C) may be useful if the final CEA decision critically depends upon estimates of monetary values.

A final caveat must be added:

> . . . certain costs cannot be valued in meaningful fashion--for example, pain and suffering--but the analysts' inability to take them to and through the valuation stage is no excuse for ignoring them in the final cost-benefit calculus. Even when it is not possible to indirectly or implicitly value such costs, it is incumbent on analysts to bring the immeasurable to the fore when measured costs and benefits are being prepared.(3)

CALCULATING RECURRENT COSTS

Personnel, Fringe Benefits, and Consultants

Salaries and wages typically represent between 33 percent to 75 percent of total primary health care program costs. Because they often are the largest single cost item, care should be taken in calculating the total. Table A-3 illustrates one way to calculate personnel costs. Key steps in this process are described below.

Table A-3.--Illustration: Calculating Personnel Costs

PERSONNEL Name/Position	No. (a)	Time/Effort Percent/Days (b)	Compensation Annual/Daily (c)	Other 1/ (d)	Subtotal (e=axbxc+d) (e)	Fringe 2/ Rate/Amt (f)	TOTAL (g=e+f) (g)
Village health workers	15	560 hrs/ea	$.80/hr		$6,720		6,720
MOH nurse supervisors	2	21% time on project	$4,500/yr	$400	$2,290	1,260 a/ 34 b/	3,584
Village health committee members (2 villages x 5 members)	10	10 days/yr	$4/day		400		400
Subtotal					$9,410	1,294	10,704
CONSULTANTS							
Health Educator	1	10 days	$35/day		$350		$350
TOTAL					$9,760	$1,294	$11,054

1 Other personnel charges, e.g., overtime, commissions, bonuses.

2 Fringe benefit calcuation:
a/ health and life insurance, holidays, sick leave, vacation = 55% of total compensation (e).
b/ health insurance @ $41 each, uniform allowance @ $40 each x 21% of time spent on project

First, identify all personnel who are connected in any way with the program (community health workers, promotors, supervisors, nurses, drivers, physicians, administrators). Include clerical and maintenance staff, volunteers, and consultants. Sometimes, it will be important to include Ministry of Health personnel (planners, trainers) or personnel from organizations that provide support to the primary health care program (e.g., drivers from the Ministry of Transportation). The example in table A-3 lists four kinds of personnel in column (a).

Second, calculate the amount of time each person spends on the program during the study period. Only that portion of a worker's time that is allocated to the program should be considered a cost item. For example, if health workers spend 4 hours out of a normal 40-hour work week on primary health care, then only 10 percent of the workers' compensation should be charged to the primary health care program. Analysts may want to check with local health planners and administrators to insure that time allocations are reasonable. These figures may be expressed as actual time spent (hours, days, weeks, months) or as percentages of total time spent on the program. Quite often, workers have no idea how much time they spend performing different activities. Supervisors or the workers themselves can keep an activity log for a week or so to help insure that these estimates are correct.

The calculations in table A-3, column (b), are based on "full-time" equaling 50 weeks (52 weeks minus 2 weeks' vacation), or 240 workdays (5 working days per week x 50 weeks less 10 holidays), or 1,920 work hours (240 days x 8 hours per day) per year.

Personnel (a)	Time/Effort (b)	
VHW	4 hrs/day x 140 days	= 560 hrs per VHW
Nurses	1 day/week x 50 weeks	= 50 days or 21% per nurse
Members	1 day/mo x 10 months	= 10 days per VHC member
Consultant		= 10 days

Third, determine the compensation paid to each worker. Often the Ministry of Finance or the Ministry of Health have already compiled salary and fringe benefit figures, so check there to avoid duplicating work. Salary costs should be counted as gross, or pre-tax salary. The figures may be listed as annual rates; however, in some cases, they will be noted as hourly, daily, weekly, or monthly rates. Hypothetical compensation costs for the four types of personnel are shown in column (c).

Personnel (a)	Rate	Compensation (c)
VHW	Hourly wage	$ .80/hr
Nurses	Annual salary	$4,500/yr
VHC members	Daily wage (equivalent)	$ 4/day
Consultant	Daily fee	$ 35/day

There are two ways to compute the cash value of the contributed time of volunteers. For those who receive salaries or wages elsewhere (e.g., volunteer nurses and physicians), use that salary. For those who do not, use the compensation rates paid to workers who do equivalent work (e.g., community health workers or maintenance mechanics). In table A-3, the prevailing daily wage rate for village laborers ($4) was used to estimate the value of volunteered time of village health committee members. Add in any additional compensation for overtime. In the example, the nurses receive $400 in overtime, which brings their total compensation to $2,290.

Fourth, multiply the amount of time each person spends on the program (column b) by the compensation figures (column c) to compute the computation for personnel, shown in column (e).

Personnel (a)	Time (b)	Compensation (c)		Subtotal (e)
VHW	15 VHW x 560 hours	@ $ .80/hr	=	$6,720
Nurses	2 nurses x 21% + overtime	@ $4,500 + $200/yr	=	$2,290
VHC members	10 members x 10 days	@ $4/day	=	$ 400
Consultant	1 health educator x 10 days	@ $35/day	=	$ 350

Fifth, add the cost of fringe benefits, if these are not included in personnel costs. Employer contributions to medical plans, insurance plans, social security, and other benefits are sometimes computed as a percentage of total salary. Some fringe benefits have to be computed separately. For example, consultants are usually paid an hourly or daily rate, or sometimes a flat honorarium. They do not usually receive fringe benefits. In the example shown in table A-3, column (f), only the Ministry of Health nurse supervisors are entitled to fringe benefits.

Personnel (a)	Fringe Benefits (f)			
Nurses	Health insurance	@ $41/each		
	Uniform allowance	@ $40 each		
	Subtotal	$81 x 21% x 2	=	$34
	55% of compensation	$1,145 x .55 x 2	=	$1,260
	Total Fringe Benefit costs		=	$1,294

Sixth, sum all personnel cost items to obtain the total personnel costs (column (g) in the example).

Travel and Transportation

This category of costs includes all transportation costs attributable to the primary health care program alternatives, whether they be for transporting people or supplies. Travel and transportation often make up a significant proportion of the costs of outreach services, supervision, and training. They may also account for a significant portion of the costs of imported supplies, materials, and equipment. Table A-4 illustrates how to calculate the most common of these costs: staff (and consultant) travel and per diem, vehicle operation and maintenance, and shipment of supplies, materials, and equipment. The calculation steps are similar for each of these costs.

1. Identify all of the travel and transportation that occurred or will occur during the study period.

2. Compute the cost of each item.

3. Sum to obtain the total.

Staff Travel and Per Diem

If a number of trips are made to the same site, it may be easier to multiply the number of trips by their average cost. Table A-4 shows that the nurse supervisors make a total of 2 trips from the city to the capital and 22 from the city to the program site. The number of trips was multiplied by their average cost (2 x $65 = $130) for the trips from the city to the capital and (22 x $7 = $154) for the trips to the program site.

Next, compute the per diem, or daily allowances for hotels and meals. Table A-4 shows that the nurse supervisors receive $43 per diem for the four days in the capital, for a total per diem cost of $172. There are no per diem costs for time spent at the program site, since nurses do not stay there overnight.

Sometimes staff and consultants conduct nonprogram activities during their travel. In those cases, the program should be charged only for the portion of the travel and per diem directly attributable to the program. For example, if the nurse supervisors spend half of their time in the capital on primary health care program work and the other half on Ministry business, then only half of the travel and per diem should be charged to the primary health care program.

Vehicle Operation and Maintenance

There are two ways to compute these costs. The first is to identify the actual expenditures for gasoline, oil, lubrication service, repairs, and maintenance. All expenses that are incurred on behalf of the primary health care program should be identified and computed. Table A-4 shows a sample of actual charges in one program for gasoline, oil, maintenance, and insurance totaling $2,436. If vehicles are used for more than one program, the costs should be apportioned according to use. For example, if the total mileage is known, divide that into the mileage attributable to the program, or use the proportion of time (days, weeks) that the vehicles are used for program work.

The second approach is often used by organizations with a motor pool. The total costs of operating the motor pool are computed and divided by some convenient unit, such as the total number of vehicles, the total number of miles driven during the year, or the total number of vehicle-days. This procedure produces a factor which can then be used to estimate the total cost of a particular program alternative. Here is an example of that approach.

Health Center Motor Pool

• Total km driven (all vehicles)	4,866	(100.0%)
• Total km driven (PHC program)	565	(11.6%)
• Total motor pool costs	$21,000	(100.0%)
• Pro-rated PHC costs $21,000 x 11.6%	= $ 2,436	

Table A-4.--Illustration: Calculating Travel and Transportation Costs

TRAVEL

Itinerary	No. trips x cost	TOTAL
Air travel of nurse supervisors, RT (from city to capital)	2 @ $65	$130
Surface travel of nurse supervisors from city to PHC program site (bus)	22 @ $ 7	$154
Subtotal		$284

PER DIEM

Item	No. days x per diem	TOTAL
Nurse supervisor per diem in capital city	4 @ $43/day =	$172
Subtotal		$172

TRANSPORTATION

Description	No. units x unit cost	TOTAL	
Land Rover, local transportation			
- Petrol	1,300 ltrs x $1.05/ltr	$1,365	
- Oil	100 ltrs x $2.00/ltr	200	
- Maintenance	4 repairs x $75 ave.	300	
- Insurance		571	$2,436
Shipment of DPT vaccine and medical supplies			
- Airfreight		$ 332	
- Trucking		56	$388
Shipment of supplies from city to health center (pro-rated 25% of shipment cost	Total shipment = 400 kilo @ cost of $80 PHC program supplies = 100 kilo (25%) Charge to program $80 x 25%	20	$ 20
Subtotal			$2,844

Summary:	
- Travel	$284
- Per Diem	$172
- Transportation	$2,844
TOTAL	$3,300

Shipping Costs

The cost of shipping supplies, materials, and equipment can be divided into two categories: international and domestic. International costs can often be taken from shipping invoices or estimates provided by the carrier. Airlines, shipping lines, and trucking lines usually include a description of the shipment, the dates, and the charges in their statements.

Domestic shipping charges, particularly airfreight, will often be billed in the same way. When such information is available, the actual expenditures can be calculated easily. When this information is not available, the costs may have to be estimated based on weight and distance factors. Some examples are shown below.

- Actual Expenditures

Description	Units	Unit Costs	Charges
- Airfreight--DPT vaccines and medical supplies	NA	NA	$ 332.00
- Trucking--office equipment	NA	NA	56.00
- Total			$ 388.00

- Pro-rated Costs

Total shipment of supplies to health center = 400 kilos at a total cost of $80. Program supplies = 100 kilos (25%). Charge to project = $80 x 25% = $20.

See table A-4 for a suggested format for displaying these costs.

Materials and Supplies

Recurrent costs for materials and supplies, particularly drugs, are also a major program item. Table A-5 illustrates one way to calculate these costs.

First, list all of the relevant materials and supplies used or that will be used in the program during the study period. Second, determine the amount of materials and supplies actually used or expected to be used during this period. One way to do this is to conduct an inventory of all relevant materials and supplies at the beginning of the time period and at the end. A sample calculation might look like that shown below.

	DPT (cartons)	Medical kits
• Inventory on hand at start of project	60	35
plus		
• Amount received during project period	+ 115	+ 0
minus		
• Inventory on hand at end of project	- 75	- 20

3. Compute the annualized cost of each item (to do this both the life expectancy of each item and the rate of interest must be determined.

4. Determine the proportion of the item to be charged to the program.

5. Sum the total.

Current value can be established in one of several ways. If the item to be purchased is new, the market price can be used. If the item is used, the analyst can check the market prices of comparable items or estimate the replacement cost of the item. For example, if a four year-old Land Rover is to be used, the analyst might check the prices of comparable vehicles or ask a mechanic what it would cost to replace the vehicle with a similar one.

There are no clear-cut rules for establishing expected life. The period may be relatively short for medical equipment, say two years, moderate for vehicles, say seven years, and much longer for buildings, say 25-30 years. The analyst should use the remaining life expectancy of used items, not the life expectancy at the time of original purchase. Purchasing agents or government accountants may be able to provide standard life expectancies for common items.

With this information the portion of the total cost of the item is calculated by dividing the current value of the item by its life expectancy. For example, a vehicle that is currently valued at $10,000 and has a remaining life expectancy of 5 years would have an annualized cost of $2,000 ($10,000/5). One-fifth of the total value is depreciated, or used each year.

Depreciation is not the only cost involved in calculating annualized costs, however. The undepreciated portion of the capital item represents an investment of resources that could have been used some other way. For example, the cost of the $10,000 vehicle not only includes the $2,000 depreciation for the first year, but the loss of interest on the remaining $8,000. If that money could have been put in a savings account at 8 percent interest, it would have earned $800. Thus, the total cost of the vehicle is actually the depreciation plus the lost interest--$2,800.

There are two ways to compute the annualized cost of a capital item that includes depreciation and interest. The first is to use the following formula:

$$a(r,n) = \frac{[r(1+r)^n]}{[(1+r)^n-1]} \times CV$$

where a = the annual cost
r = the rate of interest
n = the life expectancy of the item, expressed in years
CV = the current value of the capital item

The rate of interest should be determined for each item because they sometimes vary from item to item (they may also vary from year to year). Interest rates are usually set for the government by a senior official in the Ministry of Finance or the Ministry of Health, and it would be appropriate to use these rates when the exact rates are unknown.

Suppose a Land Rover costs $10,659, has a life expectancy of 10 years, and the current rate of interest is 15 percent. The annual cost would be

$$a(.15, 10) = \frac{[.15(1.15)^{10}]}{[(1.15)^{10}-1]} \times \$10,659 = \$2,124$$

The second way is to use an "annualization table," such as the one shown in table A-6, which shows annualization factors for capital items with different expected lifetimes at different rates of interest.

First, find the 15 percent interest rate column; then locate the factor for the tenth year. This is .1993. Second, multiply the current value of the item ($10,659) by this factor: .1993 x $10,659 = $2,124. This is the annual capital cost of the vehicle.

Capital costs should be apportioned in the same way as other costs. In the example shown in table A-7, the Land Rover is shared with other programs. It is used for primary health care 45 percent of the time. Thus, multiply $2,124 x 45% to get the capital cost of $956, which is the annual cost to be charged to the primary health care program. The other capital items are also shared and their costs are pro-rated.

For multi-year projects the costs have to be computed for each year the project will be in operation and discounted to determine the present value. Procedures for doing this are described in Appendix D.

COMPILING TOTAL COSTS

The final step in the cost calculation is to present the cost information for each alternative being studied. It is often useful to present the totals of each line item as well as the grand total. This makes it easier to compare items that vary. Table A-8 summarizes the cost data for the example that has been followed through this appendix as Alternative A, together with data for two other alternatives. Procedures for analyzing these data can be found in Appendix C.

NOTES

1. Kenneth E. Warner and Bryan R. Luce, Cost-Benefit and Cost-Effectiveness Analysis in Health Care (Ann Arbor, MI: Health Administration Press, 1982), p. 78.

2. Ibid., p. 80.

3. Ibid., p. 82.

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Table A-6

Annualization Factors for Determining Annual Cost of Facilities and Equipment for Different Periods of Depreciation and Interest Rates*

Lifetime of Assets (n)	*Interest Rates (r)* 5%	10%	15%
1			
2	0.5378	0.5762	0.6151
3	0.3672	0.4021	0.4380
4	0.2820	0.3155	0.3503
5	0.2310	0.2638	0.2983
6	0.1970	0.2296	0.2642
7	0.1728	0.2054	0.2403
8	0.1547	0.1874	0.2229
9	0.1407	0.1736	0.2096
10	0.1295	0.1627	0.1993
11	0.1204	0.1540	0.1911
12	0.1128	0.1468	0.1849
13	0.1065	0.1408	0.1791
14	0.1010	0.1357	0.1747
15	0.0963	0.1315	0.1710
16	0.0923	0.1278	0.1679
17	0.0887	0.1247	0.1654
18	0.0855	0.1219	0.1632
19	0.0827	0.1195	0.1613
20	0.0802	0.1175	0.1598
21	0.0780	0.1156	0.1584
22	0.0760	0.1140	0.1573
23	0.0741	0.1126	0.1563
24	0.0725	0.1113	0.1554
25	0.0710	0.1102	0.1547
26	0.0696	0.1092	0.1541
27	0.0683	0.1083	0.1535
28	0.0671	0.1075	0.1531
29	0.0660	0.1067	0.1527
30	0.0651	0.1061	0.1523

*Annualization Formula: $a(r,n) = \frac{[r(1+r)^n]}{[(1+r)^n - 1]}$

where r = interest rate and n= lifetime of asset for depreciation.

Source: Henry M. Levin, Cost-Effectiveness: A Primer (Beverly Hills: Sage Publications, 1983), p. 70.

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Table A-7.--Illustration: Calculating Capital Cost

Item	Initial Cost ($)	Life Expectancy (Years)	Interest Rate (%)	PHC Share (%)	Annual Cost ($)
Health center	$87,610	20 yrs	15%	20%	$2,800
Medical equipment	1,113	5 yrs	15%	25%	83
Land Rover	10,659	10 yrs	15%	45%	956
Total					$3,839

Table A-8.--Illustration: Costs for Three PHC Program Alternatives

	Alternative A	Alternative B	Alternative C
RECURRENT COSTS			
Personnel	$ 9,410	$12,400	$15,642
Fringe benefits	1,294	2,232	2,816
Consultants	350		
Materials/supplies	5,680	4,324	7,320
Travel/transport	3,300	2,382	826
Other direct costs	4,214	3,862	3,921
Subtotal	$24,248	$25,200	$30,525
CAPITAL COSTS			
Building	2,800	1,006	1,006
Equipment	83	406	102
Vehicles	956	726	954
Subtotal	$ 3,839	$ 2,138	$ 2,062
TOTAL COST	$28,087	$27,338	$32,587

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APPENDIX B

CALCULATING EFFECTIVENESS

APPENDIX B. CALCULATING EFFECTIVENESS

According to Hare, "Effectiveness means to produce the desired result, to accomplish the correct end, or to secure the relevant outcome."(1) In this manual, effectiveness is defined simply as the achievement of desired outcomes. One of the key steps in a CEA is selecting the appropriate measure(s) of effectiveness. This process actually involves two substeps:

1. Deciding which outcome criteria to use; and

2. Developing specific measures of those criteria.

In this manual a criterion is defined as a characteristic, rule, or test by which an object or event is judged. A measure is a numeral assigned according to rules to an object or event. The distinction between a criterion and a measure is useful because any given criterion can be measured in many different ways, and conversely, a given measure may or may not measure the criterion of interest. The following example of several measures of the same criterion should illustrate this point.

Criterion	Measures
Children immunized	Number of immunizations given
	Percent of children under age 5 immunized
	Proportion of children in Arayas Province effectively immunized against polio

SELECTING OUTCOME CRITERIA

Desired outcomes are usually thought of as goals or objectives. They are results, not effort, and ends, not means. However, many decisionmakers set goals and objectives that turn means into ends. For example, a Ministry of Health may have a "goal" of training 700 health workers by the end of the year or an "objective" to increase the construction of latrines and wells. These "results" are really the immediate outputs of effort, rather than the effects on client behavior or the impact on health status. Yet, decisionmakers have a legitimate right to ask how effective their programs are in achieving such immediate outputs. Therefore, the definition of effectiveness used in this manual includes achievement of immediate outputs as well as effects and impacts--all of which are defined as different types of outcomes.

As mentioned in chapter II, outcomes can be visualized as falling along a continuum from the immediate to the ultimate. Outputs are the immediate results of a program, project, or activity. They are the goods (drugs, growth monitoring charts, etc.) and services (education sessions, examinations, etc.) provided. Outputs are expected to have effects on target populations. In general, those effects can be of three types: changes in knowledge (or skills), changes in attitudes (or motivation), and changes in behavior (or practices). The effects, in turn, are expected to have an impact on the target population's health, socioeconomic, or other status.

The diagram in table B-1 obviously is an oversimplification of this continuum. In real life, this "cause-effect" chain might be much longer, with many intermediate effects; and

it might be more complex, with program outputs combining with external factors (such as good weather) to produce a desired effect. Still, this classification scheme can be useful in selecting outcome criteria for at least three reasons.

1. It provides a framework for organizing outcomes into relatively comparable classes, which can make selection more systematic and simpler.

2. It allows the decisionmaker and analyst to see where a particular outcome is on the cause-effect chain.

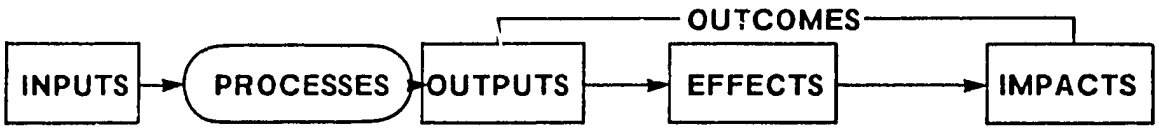
3. It can point out to the analyst and decisionmaker what they have decided not to measure.

In addition to desired outcomes, there can be undesired outcomes; and in addition to those that are expected, there can be unexpected outcomes. Thus, there are four possible categories for each outcome along the continuum. Table B-2 is an illustration of four possible health outcomes of an immunization component.

Although most CEAs are only concerned with the desired or expected outcomes, some health scientists include measures of "side effects" (undesirable outcomes) in their research because they are outcomes that decisionmakers wish to minimize. Examples are reactions from drugs, infections, and incorrect mixing of ORT salt solutions. Thus, in developing effectiveness measures for a CEA, researchers should not overlook the potential utility of some of these other types of outcome criteria.

There are many potential outcome criteria, and the analyst must be careful to select the one(s) that are appropriate to the decision being considered. Although the classification framework shown in table B-2 can be of some help, in most cases the outcome criteria should be drawn from the objective function. For example, if the objective of a particular CEA is "to identify the alternative that will maximize the number of children aged 1-5 who are immunized," then the principal outcome criterion should be children aged 1-5 immunized.

Table B-1.--Classification of Outcomes on Cause-Effect Chain



	Immediate goods & services provided	Immediate effects on target population: - Knowledge - Attitudes - Behavior	Long-term impact on target population: - Health - Socioeconomic status
Example:	ORS packets distributed	Mothers use ORS packets	Infant mortality declines

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Table B-2.--Possible Health Outcomes of Immunization

	EXPECTED	UNEXPECTED
DESIRABLE	Lower child mortality	Weight gain
UNDESIRABLE	Nausea	Jaundice

One exception to this rule, however, is when the objective is stated as a health impact criterion, such as "to reduce infant mortality." Health impacts usually are very difficult to measure. Such studies often require long-term, controlled experiments, and CEAs are usually designed to respond to short-term operational needs of host-country decisionmakers. For such applications, an intermediate effect or output criterion may be more appropriate as an outcome.

Analysts also should measure all of the significant outcomes and not limit themselves to a single criterion. In those cases where an outcome cannot be quantified, it is still important to discuss it qualitatively so that it is not ignored in the decisionmaking process.

For programs with multiple activities or objectives, a similar procedure can be used to select effectiveness measures for each objective or program component, as shown in table B-3. "Production function criteria" also can be developed for each of the components of a comprehensive primary health care program using a simple matrix, as shown in table B-4.

A listing of suggested outcome criteria and measures for primary health care service outcomes is provided the last section of this appendix.

DEVELOPING EFFECTIVENESS MEASURES

Some of the basic principles used in CEA to measure effectiveness are discussed below. A useful definition of measurement was given over 30 years ago by Stevens. According to him, measurement is "the assignment of numerals to objects or events according to rules."(2) There are three key concepts in this definition.

First, a measure is a numeral. A measure has to be quantitative. Analysts cannot use such terminology as "many, a lot, very good," or other qualifiers as measures. They have to use numerals (e.g. 25 percent over budget, 8.4 visits per day, a supervisor/CHW ratio of 1:40).

Second, although analysts simplify things by saying they measure an object or event, in fact they "actually measure indicants of the properties of objects . . . ."(3) That is, they do not measure children immunized; they measure indicators, such as the number of children injected with a vaccine. They do not measure infant mortality; they measure the number of reported infant deaths. Most measures in primary health care are indicators of one type or another.

Table B-3.--Illustration of Outcome Criteria Based on Production Function

	OUTPUTS			EFFECTS		IMPACT
Production function processes	Assessment of training needs →	Development of curriculum →	Delivery of training →	Instruction of mothers in ORT →	Use of ORS by mothers →	Health status improvement
Outcome criteria	CHWs assessed	Sessions developed	Courses offered CHWs trained CHWs passing skills test	Sessions held Mothers instructed	Mothers using ORS	Deaths from diarrhea

Table B-4.--Illustration of Worksheet for Outcome Criteria of Programs With Multiple Components or Objectives

Components	OUTPUTS	EFFECTS	IMPACTS
Growth monitoring	Growth monitoring charts distributed	Mothers using charts	Average weight by height for age
Immunization	Immunizations given	Children 1-5 fully immunized	Deaths of children 1-5
Family planning	Contraceptives distributed	Continuing users of family planning	Live births
Water and sanitation	Wells constructed	Households using well water	Cases of infant diarrhea
Maternal care	Households visited	Supervised deliveries	Miscarriages

Third, the rules used in measurement are those that apply to addition, subtraction, multiplication, and division. Most of these rules are well known. For example, five apples and four oranges cannot be added, but if they are called "pieces of fruit," they can. Some other rules are less familiar, and measurement specialists may have to be called on for help. For example, if 20 percent of the CHWs met their immunization quotas last year, and this year it jumped to 40 percent, is that a 100 percent improvement or a 20 percent improvement?*

In summary, a measure is a numeral. It is usually an indicator rather than a direct measure of an object or event, and it is manipulated according to the rules of mathematics.

Several types of measures can be calculated. They include the following:

- Count — The simplest type of measure. For any given object or event, simply count the number, such as number of visits, number of dollars, number of children immunized, etc.

* Actually, it's an improvement of 20 percentage points. One percentage can be subtracted from another but cannot be divided by another.

- **Rate** — A measure of the frequency with which some event occurs, such as miles traveled per hour or clients served per day.

- **Ratio** — Two numbers related to each other in a fraction or decimal, such as number of CHWs to number of households (1:25 or 1/25). Any fraction, quotient, proportion, or percentage is a ratio.

- **Proportion** — A special type of ratio expressing a relationship between a part and the whole. The numerator represents a portion of the total; the denominator is the total. For example, 5 nurse supervisors on a staff of 45 yields a proportion of 5/45, which can be reduced to 1/9.

- **Percentage** — A proportion multiplied by 100. Using the above proportion, the percentage of nurse supervisors on the staff (5/45 x 100) is 11.1 percent.

- **Index** — A composite of two or more numbers designed to indicate a certain condition. The Quality-Adjusted Life Year index is an example. This index attempts to adjust years of life saved by a program to reflect their quality on a scale ranging from zero, representing death, to one or ten, representing perfect health.(4)

- **Formula** — An index is often derived through a formula. Other formulas can become very complex, involving weighted components, complicated algebra, etc.

Although any of these types of measures can be used in a CEA, the most commonly used are counts, proportions, and percentages. A list of common primary health care effectiveness measures, which appears in the last section of this appendix, is primarily of these three types.

The procedure for computing effectiveness using these three types of measures is shown below. For counts, the number of units of outcome is all that is needed. This becomes the denominator in the cost-effectiveness equation, and the resulting cost-effectiveness ratio is compared with the ratio for other alternatives under study.

Counts: No. units of outcome = No. children immunized = 8,960

For proportions and percentages the effectiveness measure itself consists of a numerator and denominator. Quite often, the former is the actual number of units of outcome achieved (performance) and the latter the expected or planned units of output (objective).

Proportions:

$$\frac{\text{Actual no. units of outcome}}{\text{Expected no. units of outcome}} =$$

$$\frac{\text{No. children immunized}}{\text{No. expected to be immunized}} = \frac{8{,}960}{11{,}000} = .814$$

Percentages:

$$\frac{\text{Actual no. units of outcome}}{\text{Expected no. units of outcome}} \times 100 =$$

$$\frac{\text{No. children immunized}}{\text{No. expected to be immunized}} = \frac{8{,}960}{11{,}000} \times 100 = 81.4$$

The only difference between the proportion and the percentage measure of effectiveness is that the latter is multiplied by 100. Another proportion that is often used in health sciences research is the number of units of outcome per 1,000 or 10,000 population:

Infant mortality $\frac{\text{No. deaths under 1 year of age}}{\text{1,000 live births}}$

Crude birth rate $\frac{\text{No. live births}}{\text{1,000 population}}$

Table B-5 is a simple worksheet for developing and listing sample effectiveness measures that could be used in a primary health care CEA.

DATA COLLECTION AND ANALYSIS

Effectiveness measurement data obviously will come from different sources, depending on the particular measures selected and on whether the CEA is prospective or retrospective. In general, output data, which deal with goods and service provided, often will be available from program records. Primary health care programs often count (or could count) the numbers of services offered, ORT salt packets distributed, children immunized, and so forth.

Effects data are not likely to be available from program records. Measurement of effects often will require special surveys to determine the actual or projected change in knowledge, attitudes, and behavior. Measurement of impact data also usually requires special surveys, although registration systems may provide some useful information on mortality, fertility, and the incidence of selected diseases.

In conducting a CEA, it may be useful for a researcher to describe the data collection source and procedures for each effectiveness measure on a worksheet, such as the one shown in table B-6.

The data collected on effectiveness may be formatted in a number of ways. One is shown in table B-7. This example shows a prospective analysis of three alternative ways of providing ORT and immunization to rural communities. (Data on four effectiveness measures are displayed in table B-8.)

The data in table B-7 show that Alternative A should result in 9,762 households contacted, .814 of the target population immunized, 75.6 percent of the total households in the study areas using ORT, and a child mortality rate of 57.1/1,000. Comparing the three alternatives on these four measures, C appears to be best on all of the effectiveness measures except contact with households. If these were the only criteria considered, Alternative C would be assessed as the most effective of the three approaches.

Table B-5.--Worksheet for Selecting Effectiveness Measures

Outcome Criteria	Effectiveness Measures
Outputs (of goods and services)	
- CHW contacts with households	No. CHW contacts with households
- Children immunized	No. children aged 1-5 immunized / No. children 1-5 expected to be immunized
-	
-	
-	
-	
-	
-	
Effects (on knowledge, attitudes, and behavior)	
- Households using ORT	No. households using ORT / Total no. households x 100
-	
-	
-	
-	
-	
-	
Impact (on health)	
- Child mortality	No. deaths of children 1-5 / 1,000 children 1-5
-	

Table B-6.--Worksheet for Summarizing Data Collection Procedures for Effectiveness Measures

Measure (Total Number)	Data Source	Procedure
CHW contacts with households	CHW monthly reports	Take data from records for 6-month period in selected sites.
Children aged 1-5 immunized / Children 1-5 to be immunized	EPI records and census reports	Take data from summary sheets for 6-month period in expected selected study sites. Use latest census estimates to calculate number of children aged 1-5 in target areas.
Households using ORTx100 / Total no. households	Community surveys	Include in total number of households in baseline and follow-up surveys to be conducted in study sites.
Deaths children 1-5 / 1,000 children 1-5	Community surveys	Include in baseline and follow-up surveys to be conducted in the study sites.

Table B-7.--Illustrative Effectiveness Measures

EFFECTIVENESS MEASURES	ALTERNATIVES		
	A	B	C
No. CHW contacts with households	9,762	11,326	10,489
No. children 1-5 immunized / No. children 1-5 expected to be immunized	.814	.867	.873
No. households using ORT x 100 / Total no. households	75.6	64.6	71.4
No. deaths of children 1-5 / 1,000 children 1-5	57.1	59.5	48.6

MEASURES OF PRIMARY HEALTH CARE EFFECTIVENESS

To assist researchers interested in conducting a CEA on an issue related to primary health care delivery, a number of useful effectiveness measures are provided in table B-8. The measures are divided into three groups--outputs, effects, and impacts--which can be modified to fit a particular primary health care program, service, or activity. Table B-9 lists additional measures of behavioral effects of selected primary health care interventions. Each of these measures can be made more specific in several ways:

Measure	Example
Initial measure	Total number of contacts
1. Specify primary health care service	Total number of nutrition contacts
2. Specify target population	Total number of contacts with children aged 1-5 in Sanway District
3. Convert to ratio, proportion, or percentage	Total number of contacts/ 1,000 population

Although the particular measures selected will vary depending on the problem being studied, those presented here are among the most common ones used in assessing the effectiveness of programs, projects, and activities. As stated previously, the majority of these measures are expressed as counts, proportions, or percentages.

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Table B-8.--Suggested Measures of Primary Health Care Effectiveness

OUTPUTS (Of goods and services)

Contacts
- Total number of contacts
- No., % individuals contacted
- No., % target population contacted

Visits
- Total number of visits
- No., % individuals visited
- No., % target population visited
- No., % initial (first time) visits
- No. initial visits/No. follow-up visits
- No., % follow-up visits

Referrals
- Total number of referrals
- No., % individuals referred
- No., % target population referred

Appointments
- Total number of appointments kept
- No., % individuals appts. kept
- No., % target population appts. kept

Households served
- Total number of households served
- No., % target households served

Individuals served
- Total number of individuals served
- No., % target population served

Commodities distributed
- Total number of units distributed
- No., % individuals served
- No., % target population served

Examinations
- Total number of examinations
- No., % individuals examined
- No., % target population examined

Treatments
- Total number of treatments
- No., % individuals treated
- No., % target population treated

Prescriptions
- Total number of prescriptions
- No., % individuals served
- No., % target population served

Sessions
- Total number sessions held
- No., % group sessions held
- No., % individuals reached
- No., % target population reached

EFFECTS (On knowledge, attitudes, behavior)

Knowledge
- No., % who can recognize symptoms of disease
- No., % who know treatment protocol for (therapy)

Skills
- No., % able to carry out (preventive, diagnostic, treatment) protocol

Attitudes
- No., % who are in favor of (PHC services, activity, policy)

Motivation
- No., % willing to support (PHC service, activity, policy)

Behavior
- Total number enrollee acceptors
- No., % individuals enrolled
- No., % target group enrolled

Actives
- Total number active cases
- No., % active households
- No., % target population active
- No., % using (PHC service, intervention)

Dropouts
- Total number dropouts
- No., % household dropouts
- No., % target population dropouts

IMPACTS (On health)

Infant mortality
- No. deaths under one year of age/1,000 live births

Child mortality
- No. deaths under 5 years of age/1,000 children under 5 years

Neonatal mortality
- No. infant deaths in first 28 days of life/1,000 live births

Perinatal mortality
- No. late fetal and infant deaths in first 7 days of life/1,000 live births

Fetal Mortality
- No. abortions/1,000 women aged 15-44 years

Weight at birth
- Average weight (kg) at birth

Growth and development
- Average weight by height and age (1-4 years)
- No., % children growing normally
- Average upper arm circumference (cm) by age (1-4 years)

Malnutrition
- No. malnourished children by level of malnutrition (I, II, III)/1,000 children

Morbidity
- No. cases of disease

Maternal mortality
- No. maternal deaths/1,000 live births

Crude birth rate
- No. live births/1,000 population

Excess parity
- No. females aged 35-44 years of parity 5 or more/no. females aged 15-44
- No. pregnancies among females 10-14 years/no. females 10-14 years of age

Total fertility rate
- Total no. births to women in their lifetimes/1,000 women

Birth interval
- Average no. months between pregnancy terminations

Table B-9.--Measures of Behavioral Effects of Primary Health Care Interventions

PHC INTERVENTION	BEHAVIORAL EFFECT
NUTRITION	
Breastfeeding	Total no. breastfeeding No., % mothers breastfeeding infants No., % target group breastfeeding infants
Malnourished children using feeding packets	Total no., % children using packets No., % households using packets No., % target population using packets
Diagnosed cases of malnutrition	Total no., % treated (by level of treated severity) No., % individuals treated No., % target group treated
Growth monitoring charts used	Total no.,% children using charts regularly No., % households using charts No., % target population using charts
IMMUNIZATION	
Children immunized	Total no. children immunized against (disease) No., % children fully immunized No., % households with immunized children No., % target population immunized
ORAL REHYDRATION THERAPY	
ORT use	Total no. users of ORT No., % individuals using ORT No., % target population using ORT
Diagnosed cases of dehydration	Total no. treated No., % individuals treated No., % target group treated
MALARIA	
Malaria prophylaxis	Total no. using malaria prophylaxis No., % households using malaria prophylaxis No., % target group using malaria prophylaxis Average length of use (in days, weeks, or months)
Diagnosed cases treated	Total no. treated No., % individuals treated No., % target group treated

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Table B-9.--Measures of Behavioral Effects of Primary Health Care Interventions (continued)

PHC INTERVENTION	BEHAVIORAL EFFECT
INFANT ACUTE RESPIRATORY INFECTIONS	
Diagnosed cases of acute respiratory infections treated	Total no. treated No., % individual treated No., % target group treated
FAMILY PLANNING	
New family planning acceptors	Total no. acceptors No., % target group acceptors
Current family planning users	Total no. users No., % target group users
Months of continuous use of family planning (Prevalence)	Average months of use all users Average months of use target population
WATER AND SANITATION	
Wells	Total no. wells by type (shallow, deep, protected, unprotected) No., % households with wells No., % households using wells
Latrines	Total no. latrines by type No., % households with latrines No., % households using latrines
MATERNAL CARE	
Pregnant women receiving prenatal care	Total no. women receiving care No., % target population receiving care Average no. antenatal visits/ pregnancy
Supervised deliveries	Total no. supervised deliveries No., % supervised deliveries in target group
Mothers receiving post-partum care	Total no. women receiving care No., % target population receiving care

NOTES

1. Van Court Hare, Systems Analysis: A Diagnostic Approach (New York: Harcourt, Brace and World, 1967), pp. 202-203.

2. S. Stevens, "Mathematics, Measurement and Psychophysics," in S. Stevens (ed.) Handbook of Experimental Psychology (New York: Wiley, 1951), p.1.

3. F. Kerlinger, "Foundations of Measurement," Chap. 23 in Foundations of Behavioral Research (New York: Holt, Rinehart and Wi ion, 1964), p.417.

4. Kenneth E. Warner and Bryan R. Luce, Cost-Benefit and Cost-Effectiveness Analysis in Health Care (Ann Arbor, MI: Health Administration Press, 1982), p. 92.

APPENDIX C

ANALYSIS PROCEDURES

APPENDIX C. ANALYSIS PROCEDURES

Cost-effectiveness analysis requires a comparison of alternatives. A single program, project, or activity cannot be the subject of a CEA; nor should the comparison in a CEA be between a selected alternative and no program at all. As Thompson and Fortess note:

> Good alternatives should be identified and compared directly to each other to determine which is best. A common mistake is to compare programs to the null alternative of no program instead of to the most reasonable alternative programs.(1)

Alternatives can be identified in two ways. First, a discrete and limited number of known alternatives can be identified from experience. For example, decisionmakers may determine that they have only three alternatives ways to carry out an immunization program: mobile units, MCH clinics, or an annual campaign. A CEA of those alternatives would help them decide which one to choose.

Second, when the alternatives are unknown and continuous, a CEA can help identify the most cost-effective one (e.g., what is the optimum number of mobile clinics to purchase?). By using a mathematical model, the analyst can find the solution to such problems. Also, as mentioned in chapter I, CEAs usually are prospective, but they can also be retrospective, and they are most accurate when either the costs or the effectiveness of the alternatives are held constant.

This appendix draws on cost data from Appendix A and outcome data from Appendix B to illustrate a prospective analysis of three discrete primary health care program alternatives in which effectiveness is the variable held constant. For purposes of illustration in this discussion, the principal research question will be: which is the most cost-effective service delivery alternative for reducing child mortality through immunization and oral rehydration therapy? The three alternatives under consideration include:

1. Regular clinic services with extra immunization and ORT sessions
2. Regular clinic services with added outreach by health workers
3. Regular clinic services plus an annual immunization campaign.

The target area has 18,000 children aged 1-5. The primary health care program objectives are to immunize 11,000 children in the 1-5 age group and to have all 14,350 households in the area utilize ORT for infant diarrhea. The four elementary analysis procedures described are:

1. Cost analysis
2. Outcome analysis
3. Cost-effectiveness analysis
4. Sensitivity analysis.

Several other analytical issues and procedures are described in Appendix D, including using CEA to identify optimum solutions, dealing with unintended and multiple outcomes, cost feasibility, and cost-utility analysis.

COST ANALYSIS

In conducting an analysis of costs, the analyst is often interested in comparing the alternatives in terms of both absolute and relative differences. The first question most decisionmakers ask is, how much will each alternative cost? To answer this question, the

analyst can compare magnitudes of costs. For example, in table C-1, Alternative B would be the least costly at $27,338 and Alternative C the most costly at $32,587. Line items can also be compared. For example, the single most costly item of each alternative is personnel. Capital costs are relatively low; transportation and equipment costs vary among the alternatives.

These are the annual costs of each alternative. However, actual cash outlays may be higher in the first year for some alternatives, particularly if vehicles, equipment, or buildings have to be purchased at the beginning of the project. This may be an important issue to consider in deciding which alternative to select.

Table C-1.--Annual Cost and Outcome Data for Three PHC Program Alternatives

COSTS	ALTERNATIVES (Dollars) A	B	C
RECURRENT COSTS			
Personnel	9,410	12,400	15,642
Fringe Benefits	1,294	2,232	2,816
Consultants	350		
Materials/Supplies	5,680	4,324	7,320
Travel/Transport	3,300	2,382	826
Other Direct Costs	4,214	3,862	3,921
Subtotal	24,248	25,200	30,525
CAPITAL COSTS			
Building	2,800	1,006	1,006
Equipment	83	406	102
Vehicles	956	726	954
Subtotal	3,839	2,138	2,062
TOTAL COST	28,087	27,338	32,587
OUTCOMES			
No. CHW contacts with household	9,762	11,326	10,489
Proportion of children immunized	.814	.867	.873
Percent households using ORT	75.6	64.6	71.4
Child mortality rate	57.1	59.5	48.6

Next, the analyst can examine the relative costs of the line items by comparing the percent distribution of the costs of each alternative. This is done by dividing each line item by the total cost of the alternative and multiplying by 100. For example, in table C-2, personnel costs for Alternative A equal 34 percent of the total ($9,410/$28,087 x 100), and 45 percent of the total for Alternative B ($12,400/$27,402 x 100).

This analysis shows the relative distribution of each alternative's total cost. For example, close to half of the costs of Alternative C will go to pay personnel (48 percent) and almost one quarter (22 percent) to pay for materials and supplies. In contrast, only about one third (34 percent) of the costs of Alternative A are for personnel and one fifth (20 percent) for materials. Alternative A's transportation costs will consume 12 percent of the total compared with 2.5 percent for Alternative C.

The next question the decisionmakers are likely to ask is how much more did one program cost than another? To answer that, the analyst can examine the absolute differences in costs. One way to do this is to assign a value of "0" to the lowest cost line items and then calculate the difference for the other alternatives. For example, Alternative A has the lowest personnel cost. Alternative B's personnel cost is $2,990 greater ($12,400-$9,410). The difference between Alternatives A and C is $6,232. These absolute differences can be displayed as shown in table C-3.

Table C-2.--Relative Costs of Three PHC Program Alternatives

COSTS	ALTERNATIVES (Percentages) A	B	C
RECURRENT COSTS			
Personnel	33.5	45.4	48.0
Fringe Benefits	4.6	8.2	8.6
Consultants	1.2		
Materials/Supplies	20.2	15.8	22.5
Travel/Transport	11.7	8.7	2.5
Other Direct Costs	15.0	14.1	12.0
Subtotal	86.2	92.2	93.7
CAPITAL COSTS			
Building	10.0	3.7	3.1
Equipment	0.3	1.5	0.3
Vehicles	3.4	2.7	2.9
Subtotal	13.7	7.8	6.3
TOTAL	100.0	100.0	100.0

Table C-3.--Absolute Differences in Costs of Three PHC Program Alternatives

COST	ALTERNATIVES (Dollars) A	B	C
RECURRENT COSTS			
Personnel	0	2,990	6,232
Fringe Benefits	0	938	1,522
Consultants	350	0	0
Materials/Supplies	1,356	0	2,996
Travel/Transport	2,474	1,556	0
Other Direct Costs	352	0	59
Subtotal	0	952	6,277
CAPITAL COSTS			
Building	1,794	0	0
Equipment	0	323	19
Vehicles	230	0	228
Subtotal	1,777	76	0
TOTAL COST	749	0	5,249

The figures show that the total cost of Alternative C is $5,249 greater than that of the lowest cost Alternative B. The differences in cost of such items as fringe benefits, consultants, other direct costs, and vehicle costs are not great. But there are significant differences in other items, particularly personnel, materials and supplies, travel and transportation, and building.

How significant are the differences in costs? This last cost analysis step involves computing the relative differences in the above items by taking the actual cost of each item marked "0" and dividing it into the figures shown for the remaining alternatives and then multiplying that quotient by 100. For example, the actual personnel cost for Alternative A is $9,410. Divide that into the figure shown above for Alternative B and multiply by 100 ($2,990/$9,410 x 100 = 31.8 percent). This shows that personnel costs of Alternative B are 31.8 percent greater than for Alternative A. Alternative C's personnel costs are 66 percent greater than A's ($6,232/$9,410 x 100). Overall the cost of Alternative A is only 2.7 percent greater than B. Total cost of C is almost 19 percent greater.

This type of analysis can provide decisionmakers with the answers to some of their most basic questions: What will each program cost? Which items account for the greatest costs? How much more will one program cost than another? And, how significant are the differences in the costs of the major line items?

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OUTCOME ANALYSIS

Outcome analysis can answer the same kinds of questions. The first issue to consider is: what will each program achieve? To answer this question, start with a comparison of the magnitudes of the outcomes. It may be useful to list the counts for all of the measures as well as the proportions and percentages computed. These are displayed in tables C-4 and C-5.

The outcome data in table C-5 show, for example, that Alternative A will result in:

- 9,762 CHW contacts with households in the target area
- 8,954 children immunized, which is .814 of the target (8,954/11,000)
- 10,849 households using ORT for diarrhea, which is 75.6 percent of all the households in the area (10,849/14,350 x 100)
- 1,028 expected deaths of children aged 1-5, which would be a mortality rate of 57.1 (1,028/18,000 x 1,000).

The data also show that Alternative A would produce the largest number of households using ORT (10,849), Alternative B would result in the largest number of CHW contacts (11,326), and Alternative C would produce the largest number of immunizations and the lowest number of deaths.

Table C-4.--Illustration of Relative Differences in Costs of Three PHC Program Alternatives

COST	ALTERNATIVES (Percentages) A	B	C
RECURRENT COSTS			
Personnel	0.0	31.8	66.2
Fringe Benefits	0.0	72.5	117.6
Consultants	NA		
Materials/Supplies	31.4	0.0	69.3
Travel/Transport	299.5	188.4	0.0
Other Direct Costs	9.1	0.0	1.5
Subtotal	0.0	3.9	25.9
CAPITAL COSTS			
Building	178.3	0.0	0.0
Equipment	0.0	389.2	22.9
Vehicles	31.6	0.0	31.4
Subtotal	86.2	3.7	0.0
TOTAL	2.7	0.0	19.2

Table C-5.--Illustrative Outcome Data for Three PHC Program Alternatives

OUTCOME MEASURES	ALTERNATIVES A	B	C
No. CHW contacts	9,762	11,326	10,489
No. immunized	8,954	9,537	9,603
Proportion immunized*	.814	.867	.873
No. households using ORT	10,849	9,270	10,246
Percent households using ORT**	75.6	64.6	71.4
No. deaths, children 1-5	1,028	1,071	875
Deaths/1,000 children 1-5***	57.1	59.5	48.6

* Target is 11,000 children aged 1-5
** There are 14,350 households in the target area
*** There are 18,000 children aged 1-5 in the target area

A second concern in outcome analysis is: how much more will one program achieve than another? The absolute differences in outcomes can be calculated in the same way that the absolute differences in costs were. Table C-6, for example, shows that Alternative B will yield 1,564 more CHW contacts than A (11,326 versus 9,762); and Alternative C will result in 837 more (10,489 versus 9,762) than A. The table also shows that Alternative A should result in 11 percentage points more households using ORT than Alternative B, but .053 less of the target population immunized than Alternative B.

Relative differences among the outcomes that were expressed as ratios and percentages (proportion of target immunized, percentage households using ORT, deaths/1,000 children) are shown in table C-7. For those outcomes that were expressed as counts (numbers of contacts, immunizations, households using ORT, deaths), the procedure for computing relative differences is the same as that used to compute the relative differences in costs. That is, divide the actual outcome for the alternative marked "0" into the figures shown above for the remaining alternatives in that line. For example, 16 percent more contacts would be made through Alternative B than A (1,564/9,762 x 100); but C would result in 22 percent fewer deaths than Alternative B (196/875 x 100).

COST-EFFECTIVENESS ANALYSIS

The cost-effectiveness ratios are computed by dividing the total cost of each alternative into selected outcomes. For example, using data from tables C-1 and C-5 the cost per CHW contact, the cost per child immunized, and the cost per household using ORT are computed as follows:

Alternative A

- Cost/CHW contact $\frac{28,087}{9,762}$ = 2.88 per contact

- Cost/immunized child $\frac{28,087}{8,954}$ = 3.14 per child

- Cost/household using ORT $\frac{28,087}{10,849}$ = 2.59 per household

Cost-effectiveness ratios that are based on percentages or proportions as the effectiveness measures are calculated in the same manner but are interpreted slightly differently. The following ratios relate program costs to the proportion of children immunized. They indicate that Alternative B is the most cost-effective of the three alternatives. By dividing the program cost by the proportion of children immunized, the analyst can show how much each alternative would cost if it were 100-percent effective; that is, if all 11,000 children were immunized. Thus, Alternative C would be the most expensive, costing $5,796 more than Alternative B.

- Cost/proportion children immunized

  A $\frac{28,087}{.814}$ = 34,505

  B $\frac{27,338}{.867}$ = 31,532

  C $\frac{32,587}{.873}$ = 37,328

Table C-6.---Absolute Differences in Outcomes of Three PHC Program Alternatives

OUTCOME MEASURES	ALTERNATIVES A	B	C
No. CHW contacts	0	1,564	837
No. immunized	0	583	649
Proportion immunized	0	.053	.059
No. households using ORT	1,579	0	976
Percent households using ORT	11.0	0	6.8
No. deaths, children 1-5	153	196	0
Deaths/1,000 children 1-5	8.5	10.9	0

Table C-7.--Relative Differences in Outcomes of Three PHC Program Alternatives

OUTCOME MEASURES	ALTERNATIVES (Percentages) A	B	C
No. CHW contacts	0.0	16.0	8.6
No. immunized	0.0	6.5	7.2
No. households using ORT	17.0	0.0	10.5
No. deaths, children 1-5	17.4	22.4	0.0

Finally, at times it is useful to reformulate some outcome measures to facilitate understanding. A cost-effectiveness ratio of cost/death may give the impression that the objective is to minimize the cost of dying. If the measure can be reformulated as cost/death averted, it is less likely to be misunderstood. Assume that the analyst can calculate the number of deaths that would be averted through each alternative by comparing the current mortality figures with those of the alternatives. If current mortality is 1,438 deaths, the deaths averted and cost/death averted would be calculated as follows for Alternative A:

1,438 deaths currently
-1,028 deaths after implementing Alternative A
410 deaths averted

$28,087/410 = $68.50 per death averted

Table C-8 shows sample cost-effectiveness ratios for six measures. These data show that Alternative A is the most cost-effective program in terms of ORT use, that Alternative B is best with respect to CHW contacts and immunization, but that C is the most cost-effective in terms of deaths averted.

It is important to note that these ratios are based on the total cost of each alternative. Analysis of the cost-effectiveness of program components would require disaggregating the costs and allocating them to the various components. For example, to assess the cost-effectiveness of the immunization component, the costs attributable to that component should be calculated and then related to the appropriate outcome measures. As an illustration, if the costs of Alternative A were disaggregated for immunization and ORT, the CE ratios would be computed as follow:

- Costs

Immunization costs	$16,852
ORT costs	$11,235
Total costs	$28,087

- CE-Ratios

Cost/immunized child	16,852/8,954 = 1.88
Cost/household using ORT	11,235/10,849 = 1.04

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Table C-8.--Sample Cost-Effectiveness Ratios for Three PHC Program Alternatives

CE MEASURES	ALTERNATIVES A	B	C
Cost/CHW contact	2.88	2.41	23.11
Cost/child immunized	3.14	2.87	3.39
Cost/proportion immunized	34,505	31,532	37,328
Cost/household using ORT	2.59	2.94	3.18
Cost/percent households using ORT	371.52	423.18	456.40
Cost/death averted	68.50	74.66	57.88

At this point, the analyst may wish to summarize some of the data in one table for comparative analysis of the most relevant measures. Table C-9 shows a number of cost, effectiveness, and cost-effectiveness measures for each of the three alternatives under consideration. Alternative A appears to be best with respect to ORT. It will result in the largest use of ORT at the most cost-effective ratio. Alternative B looks attractive in several respects. It is the least costly, will produce the greatest number of CHW contacts, is only slightly behind Alternative C in respect to immunizations, and is more cost-effective than Alternative C in this area. Alternative C is the most costly of the three but will be the most effective in terms of immunization and deaths averted. It will also be the least cost-effective on all measures.

Although the analyst might eliminate Alternative A because its strengths are limited to ORT effectiveness and recommend Alternative B because it is the least costly (almost as effective as C with respect to immunization, and more cost-effective than C with respect to ORT), the decisionmakers might select Alternative C largely because it will avert more deaths and will not cost that much more than the other alternatives.

This example illustrates an important point: cost-effectiveness analysis is an input to decisionmaking. It is not a technique that makes decisions by itself. The decisionmaker may or may not accept what appears to be the most cost-effective alternative, because decisionmakers often operate in a political environment in which some criteria are given much more weight than others. In this case, the decisionmaker may decide that the large advantage that Alternative C offers in deaths averted far outweighs its higher costs. An analyst can sometimes deal with these issues by determining which measures (cost, effectiveness, cost-effectiveness) are most important to the decisionmaker and assigning weights accordingly. For example, if deaths averted is the most important criterion to the decisionmaker, it could be assigned double or triple the weight of the other criteria in the analysis. Other analytical issues in CEA are described in Appendix D.

SENSITIVITY ANALYSIS

Many of the procedures used to compute costs and outcomes involve estimates and/or assumptions. Before a categorical recommendation is made to accept an alternative, a test should be made as to whether variations in those assumptions would change the conclusion. One way to do this is through sensitivity analysis, which was discussed in chapter II.

Table C-9.--Summary Data for Three PHC Program Alternatives

MEASURES	ALTERNATIVES A	B	C
COST MEASURES			
Recurrent costs	25,248	25,200	30,525
Capital costs	3,839	2,138	2,062
TOTAL COSTS	28,087	27,338	32,587
OUTCOME MEASURES			
No. CHW contacts	9,762	11,326	10,489
No. immunized	8,954	9,537	9,603
Proportion immunized	.814	.867	.873
No. households using ORT	10,849	9,270	10,246
Percent households using ORT	75.6	64.6	71.4
Deaths averted	410	367	563
Deaths/1,000 children 1-5	57.1	59.5	48.6
COST-EFFECTIVENESS MEASURES			
Cost/CHW contact	2.88	2.41	3.11
Cost/child immunized	3.14	2.87	3.39
Cost/proportion immunized	34,505	31,532	37,328
Cost/household using ORT	2.59	2.94	3.18
Cost/percent households using ORT	371.52	423.18	456.40
Cost/death averted	68.50	74.49	57.88

Another type of sensitivity analysis that can be used is called "worst case analysis." It asks: what would happen if the worst possible error were made? For example, say that in the CEA data shown in table C-10, deaths averted were underestimated for Alternatives A and B by 20 percent and overestimated by 20 percent for Alternative C. The revised calculation would affect the conclusions. Under this assumption, Alternative A might be preferable because it would have the second lowest number of averted deaths and the lowest cost/death averted ratio.

Table C-10.--Example of CEA Data for Worst Case Analysis

	ALTERNATIVES A	B	C
Deaths averted	492	440	506
Cost/death averted	57.09	62.13	64.40

If variables in a CEA are found to be sensitive to changes in the assumptions, then there are two principal lines of action. First, the researcher can try to collect more data to improve the accuracy of the CEA and reduce uncertainty. Second, the decisionmaker can decide among alternatives by examining the assumptions and deciding which seem the most reasonable. Levin offers a concluding thought:

> In any case, it is important to inform decisonmakers about whether the results are robust or not under different assumptions about costs. It is also important to note that the problem of uncertainty does not always raise itself in a serious way. For many interventions, it is possible to get a reasonably accurate picture of costs without worrying about a sensitivity analysis. Thus, the analyst should do a sensitivity analysis only when it is clearly warranted. (2)

NOTES

1. Mark S. Thompson and Eric E. Fortess, "Cost-Effectiveness Analysis in Health Program Evaluation," Evaluation Review, Vol. 4, No. 4, August, 1980, p. 566.

2. Henry M. Levin, Cost-Effectiveness: A Primer (Beverly Hills: Sage Publications, 1983), p. 92.

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APPENDIX D

ADDITIONAL ISSUES IN COST-EFFECTIVENESS ANALYSIS

APPENDIX D. ADDITIONAL ISSUES IN COST-EFFECTIVENESS ANALYSIS

The cost calculation techniques described in Appendix A should be sufficient for basic cost-effectiveness analysis. However, some studies may require more sophisticated costing techniques. The most common of these--economies of scale, shadow pricing, foreign exchange conversions, inflation, and net cost and effects--are described and illustrated in this appendix.

ECONOMIES OF SCALE AND MARGINAL COSTS

An understanding of the distinction between average cost and marginal cost is necessary to understand the concept of scale economies. The average cost of a program gives a point summary of economic performance at a given level of output. Average cost is merely the total cost of a program alternative divided by its total output. But this is not a complete picture. Costing data are more valuable for planning if they show how costs change as the program expands or contracts. It is here that the concept of marginal cost plays a key role.

Marginal cost is the addition to (or subtraction from) total cost caused by expanding (or contracting) services. For example, if it costs $500 to serve the first 100 children at a primary health care community clinic and only $75 to serve the next 50 children, then the marginal cost of serving the 150th patient is equal to $1.50, or $75/50. The average cost of serving 150 patients is $3.83, or $575/150.

An example should illustrate this distinction. Suppose a primary health care program currently reaches 100 households, and there is a need to reach an additional 50 households. To expand, the health team needs transportation. Suppose that there are three feasible alternatives, and they are:

1. Hire a vehicle and driver to take the health team to households in the target community.
2. Purchase a vehicle and pay for the operating and maintenance costs.
3. Pay travel allowances to the health team to allow them to travel as they wish to reach the target community.

To select the preferred alternative, the first step is to cost each of these alternatives, following the guidelines described in Appendix A. For this example, assume that 50 additional households will be reached by any of the three alternatives. Table D-1 shows that the cost of expanding the program (the marginal cost per household, column f) is lowest for Alternative 1 (hiring a vehicle and driver). It will only cost $2 to serve each of the additional 50 households. Alternative 2 would cost three times as much ($6), and Alternative 3, four times as much ($8) per extra household served.

Economies of scale exist with Alternative 1. The greater the number of households served, the less it costs to serve each additional household. In other words, the marginal cost per additional household would be less than the average cost per household. From table D-1 these costs are:

	Average Cost US$	Marginal Cost US$	
• Existing Program	5.00	--	
• Alternative 1	4.00	2.00	Economies of scale
• Alternative 2	5.33	6.00	Diseconomies of scale
• Alternative 3	6.00	8.00	Diseconomies of scale

Table D-1.--Illustration of Marginal Costs of Alternative Primary Health Care Expansion Strategies

ALTERNATIVES	(a) Total Cost	(b) Total no. households covered	(c) Average cost per household (a/b)	(d) Extra total cost (a-500)	(e) Extra number households covered (b-100)	(f) Marginal Cost per household (d/e)
Existing primary health care program	500	100	5.00	-	-	-
Alternative 1 Hire vehicle and driver for team	600	150	4.00	100	50	2.00
Alternative 2 Purchase vehicle for team	800	150	5.33	300	50	6.00
Alternative 3 Provide travel allowance for mobile team	900	150	6.00	400	50	8.00

Alternatives 2 and 3 exhibit diseconomies of scale; that is, the greater the number of households served, the more it will cost to serve each additional household.

Economies of scale usually occur when fixed costs do not increase as services are expanded. The program has "excess capacity" (unused clinic beds, staff with available time, an underutilized Land Rover) that can be used at no extra cost. The extra costs of serving more people usually are limited to the variable costs (medical supplies, gasoline, etc.). When there is little or no excess capacity (no unused beds, no available staff time, etc.), then additional fixed costs may have to be incurred to permit expansion. In this case, there usually is an increase in average costs, marginal costs, and total costs. Alternative 2 (to purchase a vehicle) is an example of incurring additional fixed costs with resulting diseconomies of scale, because the cost of the vehicle is so great that it raises the average, marginal, and total cost of service.

FOREIGN EXCHANGE

All costs should be calculated in the currency of the host country. However, if the program relies on imported items that must be paid for with foreign exchange, then this presents two problems. First, official foreign exchange may be artificial, and shadow

prices will have to be used to compute the actual costs of imported goods. For example, one Latin American country recently had an "official" exchange rate of 40:1 and a "black market" exchange rate of 120:1. Calculating the cost of imported items under the official exchange rate would result in a cost three times less than the real costs. In effect, the government's official exchange rate subsidizes the health program and should be added to the project cost. This is a case where the official exchange rate does not reflect the true price of foreign exchange and a shadow price for foreign exchange should be calculated. The cost of items should then be calculated according to the shadow price of foreign exchange.

The second problem is that foreign exchange may be so limited that one or more of the alternatives being studied may not be feasible. For example, government restrictions might be such that the project could not obtain enough foreign exchange to import needed drugs. Alternatively, the foreign exchange might be available, but import restrictions might limit the amount or types of items that can be imported. A CEA must account for these nonmonetary constraints.

ADJUSTING FOR INFLATION

Inflation has played a key role in costs over the last decade and is likely to be important in the future as well. Often, adjustments must be made for inflation to determine the true costs of various alternatives. This is particularly so when inflation varies among cost categories. For example, suppose that one alternative for expanding services to rural communities is labor intensive (involves a large number of CHWs who are located in the communities) and another alternative is travel intensive (involves a small number of health teams that travel among communities). Personnel costs are likely to make up a significant proportion of the total costs of the first alternative, while travel and transportation costs will probably be significant for the second. If labor costs are expected to be stable and fuel costs are expected to rise over time, then that should be taken into account in the analysis, as shown below.

(a) Current cost of fuel--$1,000

(b) Annual rate of inflation--25%

(c) Inflated cost (c = a + (a x b))--$1,250

COMPUTING PRESENT VALUE

If an alternative is to last for more than 1 year, then economists usually discount costs and outcomes to obtain an estimate of the present value of the alternatives. This is particularly useful if the alternatives have different lifetimes. Discounting is usually applied to the total annual cost of an alternative, but it can also be applied to individual items, as illustrated in table D-2.

Alternative A involves fuel costs over 3 years. The costs shown include adjustments for an inflation rate of 25 percent annually. In this example, Alternative A appears to be the most costly. However, when the present value of the fuel costs in years 2 and 3 is computed, A is actually less costly than C and B. Again, the rationale for computing present value is that the funds for years 2 and 3 could be invested and earn interest, which would offset some of the cost.

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Table D-2.--Computing the Present Value of Fuel Costs for Multi-year Primary Health Care Alternatives

	ALTERNATIVES (US $)		
	A	B	C
Year 1	1,250	2,000	4,500
Year 2	1,563	2,500	
Year 3	1,953	—	—
TOTAL COST	4,766	4,500	4,500
Present Value	4,086	4,174	4,500

The formula for computing present value is $PV = c/(1+r)^n$. Assuming an interest rate of 15 percent, the present value of the fuel cost for alternative A would be computed as follows:

- Present value fuel $= \$1,250 + 1,563/(1+r) + 1,953/(1+r)^2$
  $= 1,250 + 1,563/(1.15) + 1,953/(1.15)^2$
  $= 1,250 + 1,359 + 1,477 = \$4,086$

Using a present value table (see table D-3), the calculation becomes:

- Present value fuel $= \$1,250 + (1,563 \times .8696) + (1,953 \times .7561)$
  $= 1,250 + 1,369 + 1477 = \$4,086$

Outcomes also can be discounted. For example, most parents would prefer to have their children immunized now rather than next year or the year after. Assuming a discount rate of 20 percent, as shown in table D-4, the present value of immunizing 1,500 children over 3 years would be equivalent to immunizing 1,264 children in year one.

NET COSTS AND NET EFFECTS

Thus far, this paper has only considered calculations of gross costs and effects. Some economists also use net costs and effects, and compute a net cost-effectiveness ratio. In defining the net costs of an oral rehydration therapy program, Shepard and Cash wrote:

> Net costs are gross costs less savings in health resources resulting directly from the activities. Savings generally lie in decreased hospitalization, reduced use of intravenous therapy and reduced use of antibiotics and antidiarrheal drugs.(1)

Therefore, if an ORT program cost $5,000 but resulted in $2,000 in savings because fewer children came to the hospital for treatment, then the net cost would be $3,000.

Table D-3.--Present Value Table

$$PV = \frac{c}{(1+r)^n}$$

Period	1%	2%	3%	4%	5%	6%	7%	8%	9%	10%	12%	14%	15%	16%	18%	20%	24%	28%	32%	36%
1	.9901	.9804	.9709	.9615	.9524	.9434	.9346	.9259	.9174	.9091	.8929	.8772	.8696	.8621	.8475	.8333	.8065	.7813	.7576	.7353
2	.9803	.9612	.9426	.9246	.9070	.8900	.8734	.8573	.8417	.8264	.7972	.7695	.7561	.7432	.7182	.6944	.6504	.6104	.5739	.5407
3	.9706	.9423	.9151	.8890	.8638	.8396	.8163	.7938	.7722	.7513	.7118	.6750	.6575	.6407	.6086	.5787	.5245	.4768	.4348	.3975
4	.9610	.9238	.8885	.8548	.8227	.7921	.7629	.7350	.7084	.6830	.6355	.5921	.5718	.5523	.5158	.4823	.4230	.3725	.3294	.2923
5	.9515	.9057	.8626	.8219	.7835	.7473	.7130	.6806	.6499	.6209	.5674	.5194	.4972	.4761	.4371	.4019	.3411	.2910	.2495	.2149
6	.9420	.8880	.8375	.7903	.7462	.7050	.6663	.6302	.5963	.5645	.5066	.4556	.4323	.4104	.3704	.3349	.2751	.2274	.1890	.1580
7	.9327	.8706	.8131	.7599	.7107	.6651	.6227	.5835	.5470	.5132	.4523	.3996	.3759	.3538	.3139	.2791	.2218	.1776	.1432	.1162
8	.9235	.8535	.7894	.7307	.6768	.6274	.5820	.5403	.5019	.4665	.4039	.3506	.3269	.3050	.2660	.2326	.1789	.1388	.1085	.0854
9	.9143	.8368	.7664	.7026	.6446	.5919	.5439	.5002	.4604	.4241	.3606	.3075	.2843	.2630	.2255	.1938	.1443	.1084	.0822	.0628
10	.9053	.8203	.7441	.6756	.6139	.5584	.5083	.4632	.4224	.3855	.3220	.2697	.2472	.2267	.1911	.1615	.1164	.0847	.0623	.0462
11	.8963	.8043	.7224	.6496	.5847	.5268	.4751	.4289	.3875	.3505	.2875	.2366	.2149	.1954	.1619	.1346	.0938	.0662	.0472	.0340
12	.8874	.7885	.7014	.6246	.5568	.4970	.4440	.3971	.3555	.3186	.2567	.2076	.1869	.1685	.1372	.1122	.0757	.0517	.0357	.0250
13	.8787	.7730	.6810	.6006	.5303	.4688	.4150	.3677	.3262	.2897	.2292	.1821	.1625	.1452	.1163	.0935	.0610	.0404	.0271	.0184
14	.8700	.7579	.6611	.5775	.5051	.4423	.3878	.3405	.2992	.2633	.2046	.1597	.1413	.1252	.0985	.0779	.0492	.0316	.0205	.0135
15	.8613	.7430	.6419	.5553	.4810	.4173	.3624	.3152	.2745	.2394	.1827	.1401	.1229	.1079	.0835	.0649	.0397	.0247	.0155	.0099
16	.8528	.7284	.6232	.5339	.4581	.3936	.3387	.2919	.2519	.2176	.1631	.1229	.1069	.0930	.0708	.0541	.0320	.0193	.0118	.0073
17	.8444	.7142	.6050	.5134	.4363	.3714	.3166	.2703	.2311	.1978	.1456	.1078	.0929	.0802	.0600	.0451	.0258	.0150	.0089	.0054
18	.8360	.7002	.5874	.4936	.4155	.3503	.2959	.2502	.2120	.1799	.1300	.0946	.0808	.0691	.0508	.0376	.0208	.0118	.0068	.0039
19	.8277	.6864	.5703	.4746	.3957	.3305	.2765	.2317	.1945	.1635	.1161	.0829	.0703	.0596	.0431	.0313	.0168	.0092	.0051	.0029
20	.8195	.6730	.5537	.4564	.3769	.3118	.2584	.2145	.1784	.1486	.1037	.0728	.0611	.0514	.0365	.0261	.0135	.0072	.0039	.0021
25	.7798	.6095	.4776	.3751	.2953	.2330	.1842	.1460	.1160	.0923	.0588	.0378	.0304	.0245	.0160	.0105	.0046	.0021	.0010	.0005
30	.7419	.5521	.4120	.3083	.2314	.1741	.1314	.0994	.0754	.0573	.0334	.0196	.0151	.0116	.0070	.0042	.0016	.0006	.0002	.0001
40	.6717	.4529	.3066	.2083	.1420	.0972	.0668	.0460	.0318	.0221	.0107	.0053	.0037	.0026	.0013	.0007	.0002	.0001	*	*
50	.6080	.3715	.2281	.1407	.0872	.0543	.0339	.0213	.0134	.0085	.0035	.0014	.0009	.0006	.0003	.0001	*	*	*	*
60	.5504	.3048	.1697	.0951	.0535	.0303	.0173	.0099	.0057	.0033	.0011	.0004	.0002	.0001	*	*	*	*	*	*

*The factor is zero to four decimal places.

Table D-4.--Illustration Calculating Present Value of Immunization

	NO. CHILDREN IMMUNIZED	PRESENT VALUE	
Year 1	500	500	= 500
Year 2	500	500/(1.20)	= 417
Year 3	500	500/(1.20)(1.20)	= 347
TOTAL	1,500		1,264

Net effects are the desired effects minus the undesired effects, such as 10,000 cases of diarrhea treated correctly minus 2,300 treated incorrectly. The net effect would be 7,700 correct treatments. The gross and net CEA for this example are shown below:

Gross CEA	Net CEA
$\frac{\$5,000}{10,000} = .50$	$\frac{\$3,000}{7,700} = .39$

Another way to conceptualize a net CEA is to compute the differences in costs and effects between an alternative and a pre-existing program. The following example of this technique is drawn from the Shepard and Cash paper:(2)

Gross cost of ORT activities	$100,000
Gross cost of pre-existing treatment	50,000
Gross number of deaths averted, ORT area	430
Gross number of deaths averted, pre-existing treatment	43

$$\frac{100,000-50,000}{538-43} = \frac{50,000}{387} = \$129 \text{ net cost per death averted}$$

DEVELOPING OPTIMAL ALTERNATIVES

Sometimes, decisionmakers need to decide which would be the most cost-effective mix of components. For example, would it better to invest the entire budget in one service or several? Suppose a decisionmaker has a $100,000 budget that can be spent entirely on immunizations, entirely on ORT, or on some combination of the two.

The decisionmaker could put the entire budget into immunization and expect to save 150 lives, which would be more cost-effective than spending the entire budget on ORT, resulting in only 100 lives saved. By splitting the budget and allocating $50,000 for each

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program, a total of 180 lives would be saved. Table D-5 illustrates the CEA for such a case. In effect, when there are a number of alternatives, the decisionmaker would select the most cost-effective one first, then the second most cost-effective alternative, and so on, until all of the available budget is spent.

Most of the examples in this manual have assumed that the alternatives are discrete and known. In chapter 1, another use of CEA was briefly described: developing optimal solutions when the alternatives are neither discrete nor known. The previous example approached this by identifying two alternative levels of funding for immunization and ORT interventions. In reality, there are really many more alternative funding levels between $0 and $100,000. If each of these were identified, the analyst would be able to select the combination of immunization and ORT services that would maximize the number of lives saved. One way to do this is to calculate the number of lives that would be saved at each cost interval. The calculations shown in table D-6 are for $10,000 intervals, assuming that the minimum level of funding possible for either program is $20,000. By looking at different combinations, the analyst can determine which will result in the most lives saved. In this example, the best combination would be:

• Immunizations	= $80,000	130 lives saved
• Oral Rehydration	= 20,000	62 lives saved
Total	$100,000	192 lives saved

- CE Ratio = $\frac{100,000}{192}$ = 521:1

It can be tedious to compute CE ratios for each level of funding. It is usually easier, and more accurate, to use graphs, mathematical formulas, or models, to identify the optimum alternative, especially when more than one constraint is being considered. One of the models that is often used in operations research is linear programming. This is a mathematical technique that is used to find a solution that maximizes or minimizes a quantity, subject to certain constraints (e.g., finding the mix of immunization and ORT services that will maximize the number of lives saved, given the constraints of a budget of $100,000 and a limit of 180 staff days).

Table D-5.--Cost-Effectiveness Analysis of Immunization and ORT Program Alternatives

INTERVENTION	COST (US $)	LIVES SAVED	CE RATIO
Immunization	A. $ 50,000	100	500:1
	B. 100,000	150	667:1
Oral Rehydration Therapy	A. $ 50,000	80	625:1
	B. 100,000	100	1,000:1

Table D-6.--Calculation of Lives Saved at Various Funding Levels

IMMUNIZATIONS		ORAL REHYDRATION THERAPY	
Costs US $	Effectiveness	Costs US $	Effectiveness
100,000	150 lives	100,000	110 lives
90,000	140 lives	90,000	104 lives
80,000	130 lives	80,000	98 lives
70,000	120 lives	70,000	92 lives
60,000	110 lives	60,000	86 lives
50,000	100 lives	50,000	80 lives
40,000	90 lives	40,000	74 lives
30,000	80 lives	30,000	68 lives
20,000	70 lives	20,000	62 lives

The following example illustrates the method. Assume the following information is available:

Service Output	Required Staff Days	Cost	Lives Saved	CE Ratio
x = 1,000 immunizations	3	$2,000	4	500:1
y = 1,000 ORT interventions	1	500	0.8	625:1

This means that it requires 3 staff days to provide 1,000 immunizations at a total cost of $2,000, which is expected to result in four lives saved. The CE ratio is the same as shown in the previous example (500:1). It only requires 1 staff day to provide 1,000 ORT interventions at a total cost of $500. However, only 0.8 lives would be saved; thus, the CE ratio is 625:1. Assuming a total of 180 staff days is available to provide both services and the total budget available for both services is $100,000, what would be the best combination of service outputs?

This question can be answered by constructing a graph (see figure D-1) through the following calculations:

1. Required staff days (3 per 1,000 immunizations, 1 per 1,000 ORT interventions) cannot exceed 180. This limitation is represented on the graph by the line described by the equation $3x + 1y = 180$, where x is the number of immunizations (in thousands) and y is the number of ORT interventions (in thousands). To find the coordinates of this line, first let $y = 0$, in which case $x = 60$. Then let $x = 0$, in which case $y = 180$. Thus, the coordinates are (60, 0) and (0, 180). This line is then carefully plotted on the graph.

2. Required cost ($2,000 per 1,000 immunizations, $500 per 5,000 ORT interventions) cannot exceed $100,000. This limitation is represented by the line described by the equation $2000x + 500y = 100,000$. The coordinates of this line are (50, 0) and (0, 100). This line is also plotted.

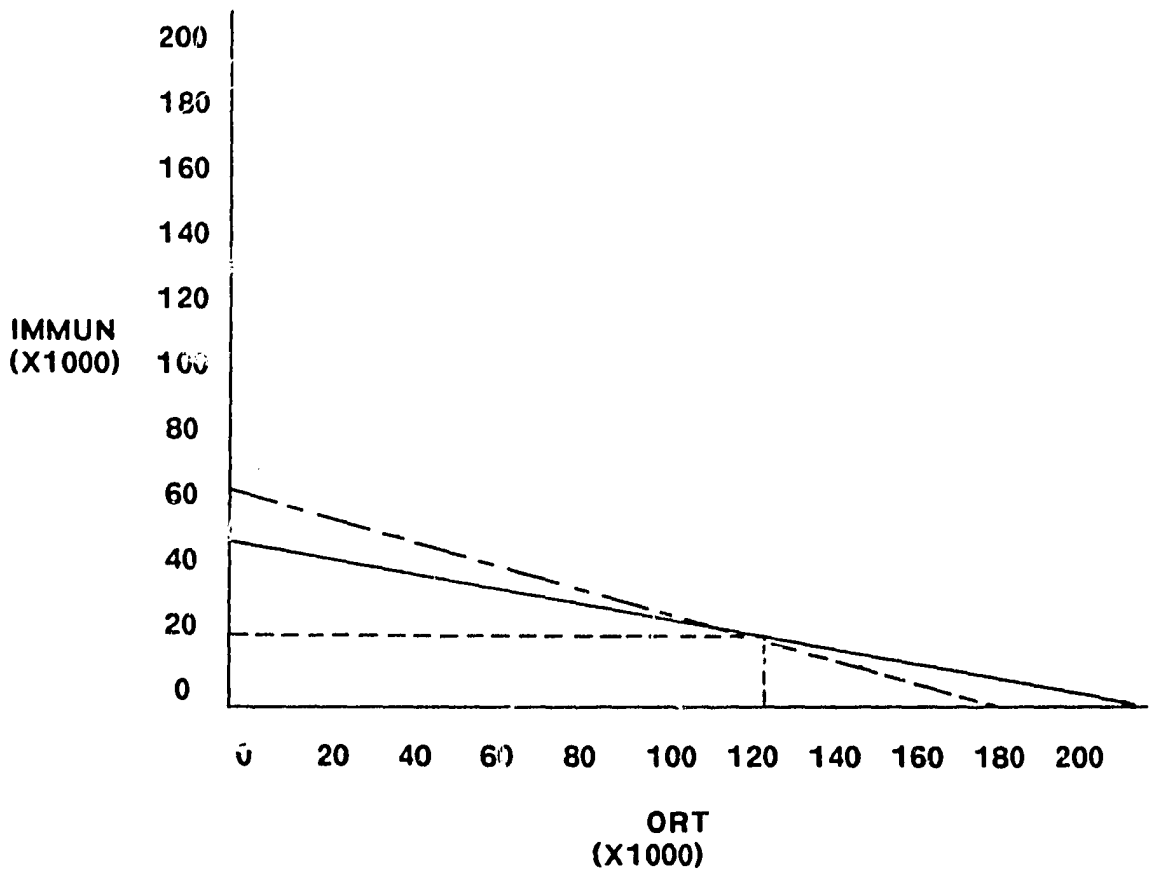
3. The equation which relates immunization and ORT to lives saved (LS) is LS = 4x + 0.8y (1,000 immunizations = 4 lives saved, 1,000 ORT interventions = 0.8 lives saved). LS is maximized when **x** + **y** have the values of the point at which the lines representing the constraints (available days + money) cross. Inspection of the graph shows this to be the point **x** = 20, **y** = 120.

4. These maximizing values of **x** + **y** indicate what action should be taken to obtain the maximum benefit (defined as number of lives saved) from the available resources. The decision, therefore, is to do 20,000 immunizations (costing $40,000 + requiring 60 staff days) and 120,000 ORT interventions ($60,000 and 120 staff days).

5. The number of lives saved may then be calculated by substituting these values in the equation LS = 4**x** + 0.8**y**. Thus, LS = 4(20) + 120(0.8) = 176.

6. The cost-effectiveness ratio of this program would be $100,000/176 = 568:1.

Figure D-1.--Identifying Optimal Solution to Cost-Effectiveness Problem



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It is important to point out that this particular technique can only be used for problems where the relationships between costs and effectiveness are linear. Other techniques have to be used when the relationships are not linear.

COST-UTILITY ANALYSIS

When it is difficult or impossible to develop measures of effectiveness, cost-utility (CU) analysis may be useful. Instead of a measure of effectiveness, selected respondents are asked to rate the alternatives in terms of perceived utilities. According to Levin,

> In essence, CU analysis compares the subjective values or utilities that are placed on each alternative by an appropriate audience with the costs of that alternative. Alternatives are then compared to see which provide the highest utility relative to cost. These alternatives are said to have the lowest CU ratios. (3)

This approach was proposed for a study in the Caribbean to assess several alternative approaches to training community health workers. Since none of the alternatives had been implemented, there was no experience to draw on to estimate how effective they would be. Instead, a panel of experts was convened and asked to rate each of the alternatives in terms of their expected effectiveness; that is, their utility. Table D-7 provides some illustrative data on three training packages that could result from such a strategy.

Levin warns that the users of the results should be involved in generating the utility estimates.

> There is one important restriction that we should apply to CU analysis. Its results should never be recommended to a secondary audience, since its procedures are permeated with the subjective judgments of the primary audience and constituencies. Since such judgments cannot be considered to be replicable among different audiences, the CU results should be viewed as unique to a particular setting rather than as being of use to some other setting.(4)

Table D-7.--Illustration of Cost-Utility Analysis of Alternative Training Packages

	ESTIMATED COST	ESTIMATED COST	COST-UTILITY
Package A	$ 10,500	.80	$ 13,125:1
Package B	$ 9,600	.75	$ 12,800:1
Package C	$ 8,400	.65	$ 12,923:1

NOTES

1. Donald S. Shepard and Richard A. Cash, "Manual for Assessing the Cost-Effectiveness of Oral Rehydration Therapy in the Treatment of Diarrhoeal Diseases," paper prepared for the Program for Control of Diarrhoeal Disease, World Health Organization, Geneva, October 17, 1983, p. 15.

2. Ibid., p. 79.

3. Henry M. Levin, Cost-Effectiveness: A Primer, (Beverly Hills: Sage Publications, 1983), p. 117.

4. Ibid., p. 117.

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GLOSSARY

ALTERNATIVE: An opportunity for choice between two or more solutions, one of which--but not more than one--may be chosen.

CONSTRAINT: A requirement or restriction on a system that reduces the freedom of decision.

CONTINUOUS VARIABLE: A variable that can assume any value within a given range. Examples are time, weight, temperature, and cost.

COST(S): The value of a good or service, which is conceptually defined as the value that could be gained by using the resources in a different way. For example, the cost of drugs could be seen as the value of using the resources to purchase some other commodity or service.

> AVERAGE COST(S): The mean cost per unit of outcome, computed by dividing the total cost by the number of units of outcome; also called unit cost.
>
> CAPITAL COST(S): Costs of items which have a life expectancy of 1 year or more, usually land, buildings, vehicles, and equipment.
>
> DIRECT COST(S): Costs that are directly attributable to a program, project, or activity, such as the cost of gasoline used by project vehicles for project work.
>
> FIXED COST(S): Costs that do not vary with program size, such as drugs, gasoline, and vehicle maintenance.
>
> INDIRECT COST(S): Costs that are not directly attributable to a program, project, or activity, but which are incurred in support of it, such as the cost of fuel to heat a cafeteria where project staff sometimes eat.
>
> MARGINAL COST(S): The increased (or decreased) cost of providing one additional (or less) unit of outcome.
>
> RECURRENT COST(S): Costs of items that are purchased and used (or replaced) within a period of 1 year or less, such as personnel salaries, medicine and supplies, gasoline, and utilities.
>
> VARIABLE COST(S): Costs that vary with program size, such as drugs, gasoline, and vehicle maintenance.

COST-BENEFIT ANALYSIS: A technique for comparing the monetary costs and monetary outcomes of alternatives. In CBA, the effect (the denominator) is expressed in monetary terms; in CEA it is not.

COST-EFFECTIVENESS ANALYSIS: A technique for comparing the costs and the effectiveness of alternative ways of achieving the same objective.

COST-EFFECTIVENESS RATIO: The ratio that is derived by dividing costs by effectiveness.

COST-UTILITY ANALYSIS: A procedure that compares the costs of alternatives with the subjectively derived ratings of those alternatives; used when effectiveness cannot be measured.

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COUNT: A measure that is expressed as an integer, such as 14 staff, 34 visits, or 59 immunizations.

CRITERION: A characteristic, rule, or test by which an object or event is judged.

DECISION: The act or process of choosing among alternatives.

DECISION VARIABLE: A variable in a decision problem that can be controlled by the decisionmaker.

DISCRETE VARIABLE: Variables whose possible values are integers. They can only be counted, not measured; examples are personnel, injections, training courses.

EFFECTIVENESS: The degree to which program or system objectives are achieved. Usually, outcomes are compared to some standard, such as the objectives that were set originally. For example, the program reached 90 percent of its target.

EFFECTS: The changes in knowledge, attitudes, and behavior (practices) among individuals, families, or communities as a result of a program, project, or activity.

EFFICIENCY: The achievement of objectives without wasting resources; the relationship of output to input. For example, in two programs that use the same amount of resources, program A, which screens 10 mothers/day, is more efficient than program B, which screens 5 mothers/day.

EVALUATION: A judgment of worth. In practice, a process for making judgments about selected objects, processes, or programs by comparing them to specific value standards (e.g., objectives) for the purpose of deciding among alternatives.

GOAL: A desired impact. In primary health care, a state of health that is desired or expected to be achieved through an activity, project, or program; for example, to reduce infant mortality.

IMPACT: A change in the status (e.g., health, standard of living) of individuals, families, or communities as a result of a program, project, or activity. For example, a reduction in infant mortality by 15 percent.

INDEPENDENT VARIABLE: A variable that is used for predicting or explaining other (dependent) variables (the "cause" in a cause-effect relationship).

INPUT: The types or quantities of resources (labor, money, material, etc.) used in a program, project, or activity; sometimes called "effort."

MEASURE: A number assigned to an object or event. Measures can be expressed as counts (45 visits), rates (10 visits/day), proportions (45 primary health care visits/380 total visits = .118), percentages (12 percent of the visits made), or ratios (45 visits/4CHWs = 11.25).

MODEL: A simplified representation of the real world. In operations research, models are usually graphic (maps, diagrams, flowcharts) or mathematical (formulas, equations).

OBJECTIVE: An effect that is desired or expected to be achieved by an activity, project, or program (e.g., to increase the use of growth charts by 50 percent).

OBJECTIVE FUNCTION: A statement or equation which expresses the relationship between the actions that a decisionmaker may take and the outcome of those actions or between the decision variable and the objective of the solution.

OBJECTIVE OF THE SOLUTION: A statement of the characteristics of an acceptable solution, usually expressed in quantified terms; for example, to maximize the number of children that can be immunized with a particular program budget.

OPERATIONAL PROBLEM: A specific question, issue, or dysfunction in an operating system that limits the attainment of system objectives. It is a problem within the operating system as opposed to an environmental, health, or other non-system problem.

OPERATIONS (or OPERATIONAL) RESEARCH: The application of science to the solution of managerial and administrative problems; a systematic, problem-solving process consisting of three phases: problem analysis, development of solutions, and testing of those solutions.

OPTIMIZE: To operate a system so that the system criterion is at its optimum value. For example, to minimize costs or maximize utilization.

OPTIMUM: The best, or more favorable, value that can be achieved given the constraints.

OUTCOME: The results of a program or activity, usually its effects or impact, but may also include outputs.

OUTPUT: The types and quantities of goods and services produced by an activity, project, or program; for example, 750 packages of oral rehydration salts distributed.

PERCENTAGE: A proportion multiplied by 100.

PRESENT VALUE: The current value of goods or services, usually applied to costs or outcomes expected in the future. The future value is discounted at a given rate to determine the present value.

PRIMARY HEALTH CARE: A strategy for making basic health services universally accessible to the world's population.

PROBLEM: (See operational problem).

PROCEDURE: A series of predetermined tasks or actions to carry out an operation, such as a physical examination.

PROCESS: A linked series of actions or operations that are directed to a specific purpose, such as a health education session.

PROGRAM: A set of organized activities designed to reach a goal.

PROPORTION: A special type of ratio expressing a relationship between the part and the whole. The numerator represents a portion of the total; the denominator is the total. For example, five male health workers out of a total of 15 health workers make a proportion of 5/15, which reduces to 1/3 or .333.

PROSPECTIVE: Future-oriented; in operations research, a study or alternative to be carried out in the future.

RATE: A measure of the frequency of occurrence of some event, such as kilometers per hour or visits per month.

RATIO: Two numbers related to each other in a fraction or decimal, such as the number of immunizations to the number of health workers. Any fraction, quotient, proportion, or percentage is a ratio.

RETROSPECTIVE: Past-oriented; in operations research, an alternative already carried out or data already collected.

SENSITIVITY ANALYSIS: An analysis that shows how a solution is affected by changes in one or more of the variables that influence its value.

SHADOW PRICING: Estimates of the true costs of goods and services that are applied, for example, to subsidized services, donated time and equipment, and other goods and services whose true value is not the same as the listed value.

SUBSYSTEM: A system within a larger system.

SYSTEM: A set of discrete but interdependent components designed to achieve a set of goals.

VALUE: Estimated or assessed worth; in operations research, the number assigned to a decision variable, such as the price set for oral rehydration salt packets.

VARIABLES: The factors in a decision problem, the value of which may change. Variables can be either controllable by the decisionmaker (decision variables) or uncontrollable by the decisionmaker (constraints, facilitating factors).

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CORRECTIONS TO THE PRICOR MONOGRAPH

OPERATIONS RESEARCH METHODS: COST-EFFECTIVENESS ANALYSIS

Despite our proofreading efforts, a number of errors were included in the CEA monograph. Corrections with their pages numbers are listed below. We apologize for any misunderstandings that these errors may have caused.

1. Page 12, Table 1-6

   DELETE: Units of Skill (E = A x C)
   INSERT: Units of Skill (E = A x **D**)

2. Page A-8, Paragraph 2

   DELETE: ...to compute the computation for personnel,...
   INSERT: ...to compute the **cost** for personnel,...

3. Page C-4, Paragraph 2

   DELETE: ...This last cost analysis step involves...
   INSERT: ...This last cost analysis step, **illustrated in Table C-4, involves...**

4. Page C-5, Paragraph 1

   DELETE: ...These are displayed in tables C-4 and C-5.
   INSERT: ...These are displayed in tables **C-5** and **C-6**.

5. Page D-10, Table D-7

DELETE:	ESTIMATED COST	ESTIMATED COST	COST-UTILITY
INSERT:	ESTIMATED COST	**ESTIMATED UTILITY**	COST-UTILITY

7. Page E-1

   DELETE: FIXED COST(S): Costs that do not vary with program size, such as drugs, gasoline, and vehicle maintenance.
   INSERT: FIXED COST(S): Costs that do not vary with program size, such **as those of a building, salaries of permanent staff, and medical equipment.**

3. The area of the figure inside both of the plotted lines (shaded) represents the set of x,y values that would not violate the constraints on either staff time or funds. The equation that relates immunizations and ORT interventions to lives saved is LS=4x + 0.8y. This equation is called the objective function and it is maximized when x and y take the particular values of one of the vertices, or "corners", produced when the constraint lines are plotted on the graph. In this case, there are three such vertices (not counting the point 0,0): 0,180, 50,0, and 20,120 (the point on the graph at which the constraint lines cross). Substituting each of these pairs of values in the objective function yields values for number of lives saved of 144, 200, and 180, respectively.

4. The above analysis tells us that, in this case, to save the maximum number of lives (200) we should do 50,000 immunizations and no ORT. The cost-effectiveness of this strategy would be $100,000/200=$500 per life saved. Notice that while this uses up the entire $100,000 available, it does not use up all the staff days--only 150 out of 180. Nevertheless, because of the relationship between unit cost of these activities and lives saved per unit activity, no strategy that siphons off funds for ORT will be as cost-effective as doing all immunizations. (A different objective function might produce a different optimum strategy and a different cost-effectiveness. For example, if each 1,000 ORT interventions yielded 1.2 lives saved instead of 0.8, then substituting the vertex values in the objective function LS=4x+1.2y would produce lives saved of 216, 200, and 224. Thus, the optimal strategy would be to do 20,000 immunizations and 120,000 ORT interventions; the cost-effectiveness of this strategy would be [(20 X $2000)+(120 X $500)]/224=$446 per life saved.)
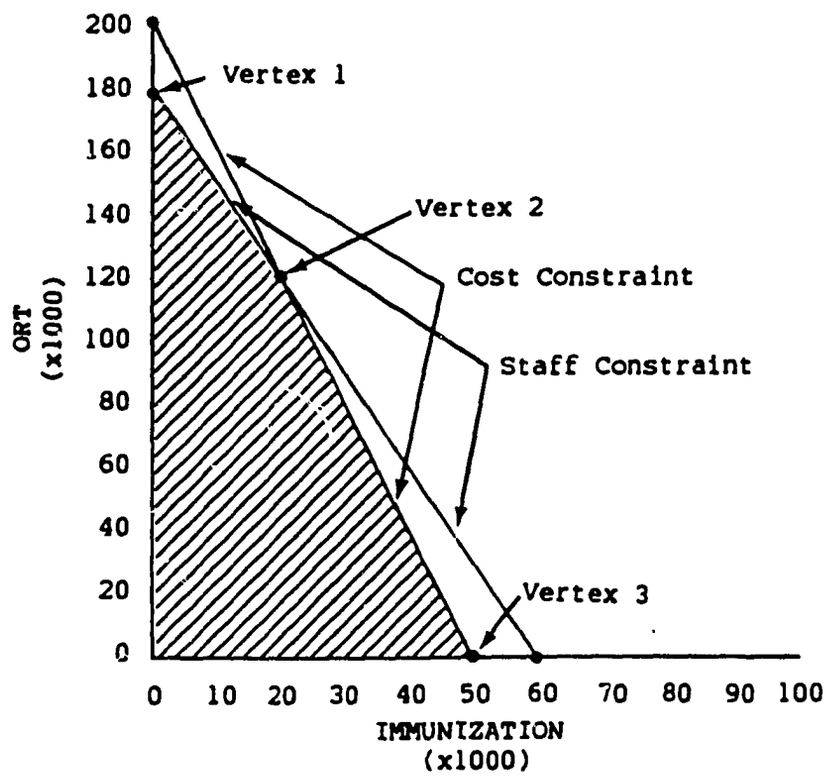
Figure D-1.--Identifying Optimal Solution to Cost-Effectiveness Problem