A Model for Applying Cost-Effectiveness Analysis to Decisions Involving the Use of Instructional Technology

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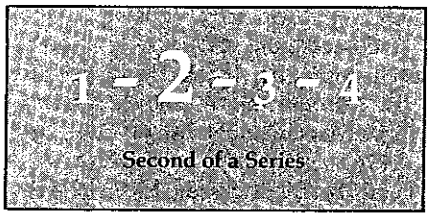

EDITOR'S NOTE

This is the second in a series of articles on the use of cost-effectiveness analysis to evaluate instructional programs. The first article appeared in the last issue of *JID* (Doughty, 1979) and provided an overview of conceptual and practical criteria for judging and designing cost-effectiveness studies. In the present article, Lent provides a detailed model of the methods of cost-effectiveness analysis as used to inform decisions about instructional development efforts, and other applications of educational technology. A companion article in the next issue of *JID* will go into further detail on the techniques of cost analysis appropriate to this context. Finally, the concluding article of this series will present an applied case study of cost-effectiveness analysis in an instructional development context that demonstrates many of the features, methods, and problems of such studies as described in the earlier articles.

Overview

As a result of difficulties encountered in attempts to apply the classical techniques of cost-effectiveness (CE) analysis to decisions facing instructional developers and educational technologists, it is apparent that those techniques require a certain degree of interpretation and adaptation if they are to be useful in this context. The following presentation describes a general model for applying CE analysis to decision situations involving instructional technology. A brief introduction to the nature of CE analysis is followed by a review of the history and problems encountered in its use within education. Finally, a six-phase model is presented for applying the methods of CE analysis to instructional technology.

Nature of Cost-Effectiveness Analysis

Determining the cost-effectiveness of something (such as an application of instructional technology) is a specialized kind of evaluation activity designed to help developers make informed decisions about the relative worth of alternative means to a given goal. Although definitions differ, cost-effectiveness can generally be defined as the relationship between something's inputs (costs) and outcomes (effectiveness) *relative* to the particular goal being served and the alternative means of achieving it. Cost-effectiveness is a relative quality of something that can be judged only in comparison to the similar property of another thing (Carpenter, 1970). One alternative is judged as more cost-effective than another if, for example, it is more effective in reaching the goal for a given level of cost or if it reaches a fixed level of effectiveness for the lesser cost (Quade, 1975).

Quade (1971) groups cost-effectiveness analysis with cost-benefit analysis, policy analysis, operations research and other management sciences as sharing the common purpose of aiding decision-making. Cost-effectiveness analysis is distinctive because it is designed to compare alternative approaches to a given goal. The cost of the alternative under consideration can generally be represented in monetary units. Effectiveness is usually not estimated in dollars, but rather is measured on a scale chosen to reflect the nature of the particular goal (e.g., achievement test scores). Thus, while CE analysis is a particularly flexible technique, it is only suitable for choosing among competing approaches to the same goal. When choices have to be made between competing goals as well as alternative activities, effectiveness must be measured in the same units as costs in order to make a meaningful comparison. Under these circumstances, the more specialized economic tool of cost-benefit analysis (comparing costs and benefits on identical scales of estimated monetary value) is more appropriate (Quade, 1971).

The nature and purposes of CE analysis make it particularly well suited for many of the decisions facing education in general and instructional technology in particular. Carpenter and Haggart (1972), and Doughty (1973, pp. 15-16) among others have suggested the variety of decisions to serve. It may be used to choose among alternative programs for achieving the same educational outcome, or to determine whether a single program is becoming more or less effective or expensive over time as a result of changes in the educational environment. The ability of cost-effectiveness analysis to assist in these kinds of decisions could impact upon the future use of instructional technology as an innovative or alternative approach to efforts at meeting educational goals under constrained budgets.

Growth of Cost-Effectiveness Analysis In Education and Instructional Technology

Over the last 10 years, increasing attention has been given to the potential

role of CE analysis in decisions regarding the design and conduct of instructional programs. For example, from 1956 to 1967 the *Office of Education Research Reports* listed four publications related to analysis activities. But in 1968, the new *Education Resources Information Center* listed 22 references under the specific descriptor "cost-effectiveness" and by the 1970's this number had grown to almost 100 references per year. Unfortunately, however, most of this attention appears to have been more rhetorical than practical. Reviews of this literature by such authors as Caffarella (1973), Vadhanapanich (1976), and most recently Levin (1978) have found that relatively few studies are actually being conducted or at least reported. Furthermore, careful consideration of the few reported studies suggests that CE analyses frequently suffer from serious methodological defects which threaten the validity and utility of their findings (Caffarella, 1975; Carnoy and Levin, 1975; Lent, Note 1; Rogers, 1976).

One explanation for this state of affairs is that the methods of CE analysis may be ill-suited to the kinds of variables present in any study of instructional programs. Dating back to some of the first attempts to conduct CE analyses in educational settings, various writers (e.g., Cogan, 1971; Grayson, 1972; Mushkin and Cleveland, 1968) began noting particular difficulties in applying the methods of CE analysis to meet the demands of their studies. Generally, these difficulties were seen to reflect the rather complicated and poorly defined nature of the variables involved in educational contexts as compared to the military, business, and engineering settings within which the analysis techniques were originally developed (Quade, 1975). In a detailed critique of the problems facing CE analyses of instructional technology, Levin (1971) concluded that the inadequate nature of our current understanding of the educational process virtually precluded any hope of meeting the basic requirements for the conduct of CE analysis.

In spite of this rather gloomy prognosis, the efforts of a number of analysts suggest that ways can be found to adapt CE analysis to serve educational decisions. The example studies and methodological suggestions of Carnoy (1976), Carpenter, Chesler, Dordick, and Haggart (1970), Doughty and Stakenas (1973), Haggart (1978), Jamison, Klees, and Wells (1978), Kazanowski (1968), Mayo, McAnany, and Klees (1975), Roid (1974), Lent (1977), and Temkin (1974) all provide evidence that the means can be found to successfully employ cost-effectiveness analysis in complicated decision situations. Furthermore, the experience gained from even relatively unsuccessful studies can suggest methodological adaptations useful in future studies (Lent, Note 1).

It is not the intent of this article (nor is there the space) to document the precise nature of the methodological problems and possible modifications required to successfully conduct CE analyses of instructional technology. A good introduction to many of these points has already been provided by Doughty (1979). Instead, the remainder of this presentation is devoted to the explication of a general model for applying the methods of CE analysis to decisions involving the use of instructional technology. This model has been derived from the suggestions in the existing literature and an extensive comparative analysis of the methods employed in reported CE studies of instructional technology. It also reflects the author's own experience and that of several of his colleagues in conducting this kind of study in a variety of educational settings. Certain aspects of the model were developed with the assistance of Temkin, Doughty, Beilby, and Stace in preparing a training session on this subject for the American Educational Research Association.

A General Model for Applying Cost-Effectiveness Analysis to Instructional Technology

A six-phase model for the conduct of cost-effectiveness analysis is described below and illustrated in Figure 1. The model is broken into phases by areas of methodological decisions and activities involved in completing a study. Overall, the process of conducting a CE analysis is seen to be only loosely linear with some phases occurring simultaneously. Within each phase, a variety of decisions and activities must be completed and, again, these often may be completed almost simultaneously or in several different orders.

Several assumptions underlie the development of this model. First, it has been designed to be used by the instructional developer or educational technologist involved in the project that is to be the subject of the study. It is assumed that such a person would be familiar with the concepts and techniques of educational evaluation, but is also likely to require occasional assistance with specific aspects of research design, instrumentation or cost analysis. That is, it is this author's opinion that CE analyses

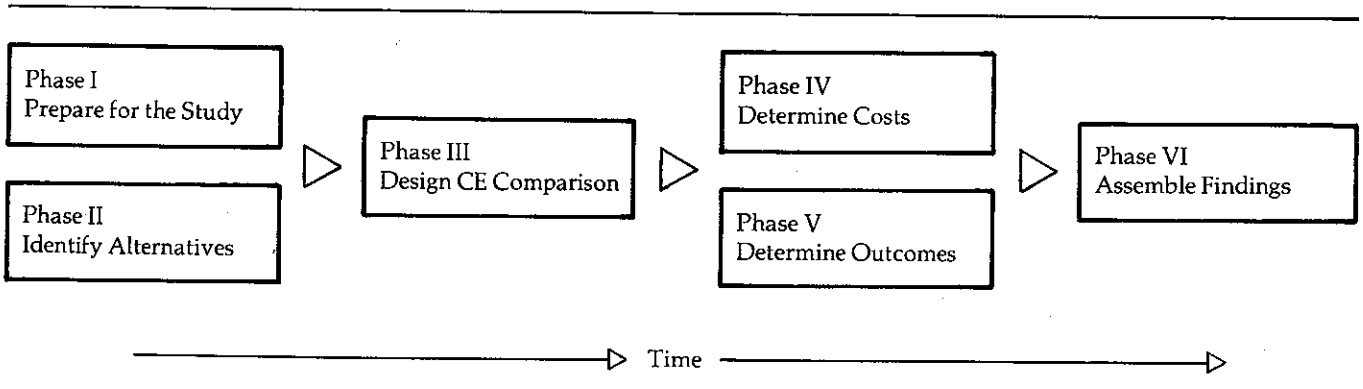

FIGURE 1. A general model for applying cost-effectiveness analyses to decisions involving the use of instructional technology.

should not be the exclusive domain of someone with a specialized background in the tools of economic analysis any more than they should require the presence of a specialist in statistical analysis. The methods of CE analysis are necessarily eclectic and the person best suited to conduct them is typically the person most familiar with the context. Finally, this model assumes that CE analyses are conducted to provide information for decision-making. The emphasis in the design of such studies, therefore, should be on creating a valid and readily interpretable study that reflects the characteristics of the specific decision situation for which it was conducted.

"Cost-effectiveness is a relative quality of something that can be judged only in comparison to the similar property of another thing."

A description of each phase of the model and the activities which comprise them follows. (It should again be noted that a companion article in this series focuses exclusively on the methods of cost analysis and thus that aspect of the model is not treated as fully here as it otherwise might have been.)

Phase I: Prepare for the Study

Cost-effectiveness analyses may or may not begin with the realization that the decision situation calls for a comparison of the costs and outcomes of alternative instructional programs or media. Often, the issue or decision at hand is viewed in some other way and only later is the necessity of a cost-effectiveness comparison realized (e.g., Lent, 1977). However, no matter when in the course of the investigation the decision to employ CE analysis is reached, a number of specific decisions must be made and information collected in order to begin the study.

Identify decision-maker(s) and audience(s). One of the first concerns in planning any CE analysis must be to ensure a clear understanding of the nature of the decision-makers who will be the primary users of the study's findings. The design, conduct, and reporting of the CE analysis will differ according to the level of decision-making (the higher the level of responsibility or decision-making, the lower the amount of detail necessary and desirable in the final study, Gephart, 1971); the program variables which the decision-makers believe are important; the information they seek and will find credible; and the process and timing of the decisions which the analysis will ultimately serve. In short, the following questions must be addressed:

- Who are the decision-makers?
- With what aspects of the instructional program are they concerned?
- What information do they want?
- How and when will they reach their decisions?

In addition to the formal decision structure, the interests of a number of other groups or individuals may have an important influence on the conduct of the study. For example, a university's decision to introduce television-based courses cannot be made without consideration for the attitudes of the faculty and students who will be involved in those courses. Answers to the following questions will help to establish the role and importance of various audiences for the study's findings.

- What groups or individuals are directly or indirectly affected by the program?
- What information would they be interested in?
- How will they influence the judgment or priorities of the decision-makers?

Determine study purposes. Cost-effectiveness analyses can be conducted to serve a variety of widely differing purposes and it is important to establish from the outset the specific framework within which the study is to be conducted. On the most general level, CE analyses can be conducted to describe the performance of existing instructional programs or to predict the performance of future programs. Perhaps most frequently, CE analyses are conducted to compare the performance of an existing program with that of a potential future program (which is typically a comparison of a traditional and an innovative, instructional technology-based program).

The specific type or function of decision-making to be served can also have an impact on the design of the CE analysis (Doughty, 1973). First, analysis may serve a *control* function when the decision-maker is concerned with managing and monitoring the flow of resources and level of output. Analysis activities may also support the function of *planning* for predicted changes in the resources or outcomes of activities. A third function is that of *evaluation* where the emphasis is on comparing the desired versus the actual costs and outcomes of an activity. Finally, analyses may be conducted to serve a *development* function in order to assist in the generation, design, and implementation of new activities.

Finally, at the most immediate and pragmatic level, the purpose of the CE analysis can be defined in terms of the specific, individual questions posed by the decision-makers to be addressed through the study. These questions may reflect a variety of different aspects and issues surrounding the subject of the study and decision situation. At least in theory, complete cost-effectiveness analyses should address each variable that plays a significant role in the final decision. The following list suggests some of the dimensions of an instructional activity about which information might be requested.

- Costs—direct and indirect, budgetary and nonbudgetary, capital and operating
- Outcomes—direct and indirect
- Relative effectiveness in achieving a goal
- Relative efficiency in achieving a goal
- Impact of changes on existing system/subsystems
- Political and organizational implications
- Consideration of intangible impacts

Plan study management. The final element in preparing to conduct a CE study is a consideration of the resources available for the study and the overall timelines and operating characteristics to be followed in conducting the study. The analyst must determine the budget available for the full study and then allocate that budget across the study's various activities. At this point it often becomes necessary to consider the deci-

sion-maker's priorities for certain kinds of information relative to the cost of collecting that information then decide to narrow the scope of the overall study.

In addition to the available financial resources, an equally important consideration is the nature of the personnel available to conduct the study. CE analyses may require a wide range of expertise in areas ranging from accounting and budgeting practice to tests and measurement, survey analysis, and participant observation. The role of such experts may only involve some minimal consulting, but larger studies may actually require the establishment of a formal team to conduct the investigation. In some cases this team should also include representatives of key decision-makers and audiences for the study.

Finally, preparations for the study should also include careful planning of the organization and timing of study tasks. While such considerations are not unique to CE analysis, the relative complexity of most decision-maker's information needs and the fact that CE studies are usually conducted to inform a decision at a particular point in time, makes it particularly important that the study be completed as planned and on schedule.

Phase II: Identify Alternatives

The second major phase of methodological activity in conducting a CE analysis involves identifying the alternatives to be compared within the study. The utility of the study's findings will ultimately depend in large part upon the nature of the alternatives chosen for comparison. Frequently, however, the nature of the alternatives under consideration by the decision-maker has not been fully established prior to the study's beginning. Furthermore, the analyst may want to introduce additional alternatives that may either outperform the original alternatives or provide an important source of extra data for comparison against those original alternatives. (For an example of this situation see Lent, 1977.)

Identifying and defining the alternatives for study then becomes one of the most creative and important activities of the whole study. Four sequential steps for completing these activities are described below. While the completion of these steps is primarily the responsibility of the analyst, the decision-maker should be involved throughout.

Identify the goal(s) of the system under study. By definition, CE analysis involves a comparison of alternative means to a given end. The process of identifying and defining possible alternatives must therefore be based upon a clear understanding of the goal(s) to be served. This requires careful consideration of the system within which the alternatives are to function and the surrounding environment or suprasystem within which that system resides.

Identify any constraints upon the way in which the system's goal(s) are achieved. In addition to understanding the nature of the goals, it is necessary to identify any constraints or requirements for achieving those goals (Kazanowski, 1968). Knowledge of constraints and requirements can then be used to establish the parameters of feasible alternatives. Typical constraints might include the scope of available resources and any untenable side effects that are likely to pertain to certain approaches to the goal's achievement. The analyst should review identified constraints carefully to ensure that they are necessary and realistic and not simply the result of tradition and unexamined assumptions.

Identify a range of existing or potential alternative means for achieving the goal(s). Working from the information on the system's goal and its constraints, along with an understanding of the decision-maker's information needs, it is now possible for the analyst to begin identifying or further defining the various alternative approaches to the goal. It should be noted that this step is to be completed even under those circumstances in which the alternatives seem fairly clear to the decision-maker. Often, an additional alternative can be considered within the CE analysis for little extra cost or effort and with great returns for the eventual utility of the study.

The outcome of this step is the selection of the particular alternatives to be compared within the CE analysis. Three specific activities comprise this step.

The first activity is designed to stimulate creative thinking regarding the range of possible alternatives. Rather than focusing immediately on specific alternatives, the analyst should identify

A Cost-Effectiveness Analysis Model

Phase I: Prepare for the study.
- Identify decision-maker(s) and audience(s).
- Determine study purposes.
- Plan study management.

Phase II: Identify alternatives.
- Identify the goal(s) of the system under study.
- Identify any constraints upon the way in which the system's goal(s) are achieved.
- Identify a range of existing or potential alternative means for achieving the goal(s).
- Describe the selected alternatives.

Phase III: Design cost-effectiveness.
- Define criteria.
- Design analytical model.

Phase IV: Determine costs.

Phase V: Determine outcomes.

Phase VI: Assemble findings.
- Assemble cost and outcome information.
- Analyze information and prepare recommendations.
- Consider uncertainties and test assumptions.

as many alternative approaches or classes of alternative approaches as possible. Answers to the following questions may suggest some of these alternatives.

- What is the current approach to the goal? Could it continue in the future? What was its predecessor? What would be the exact opposite approach?
- On what performance dimensions do the most critical differences among alternatives lie? Could alternatives be identified which represent the extreme points on each of these dimensions?
- How will the comparison of alternatives serve the information needs of the decision-makers? In what ways could additional alternatives provide a more complete picture of the trade-offs involved in the choice of a specific approach?

Examples of CE studies exist which illustrate the identification of alternatives in each of the ways suggested by these sets of questions (e.g., Carpenter et al., 1970; Lent, 1977; Mayo et al., 1975). When the subject involves the use of instructional technology, further alternatives can sometimes be identified by considering separately the two ways in which instructional technology can improve the cost-effectiveness of an educational activity: by improving instructional effectiveness and thereby bettering the rate of return on invested resources, or by reducing costs while maintaining a constant level of instructional effectiveness.

Once a range of possible alternatives has been identified, the next activity is to review these alternatives for possible inclusion within the study. The following questions should be addressed in the process of this review.

- Are the alternatives feasible within the constraints set for the goal's achievement?
- Do they represent critical competitors (or are some of them only "straw men")?
- Can they be designed to show their best sides within the present study?

The concluding activity of this step is to make the final selection of the alternatives to be compared within the CE analysis. This selection should be completed in consultation with the decision-maker and is likely to involve some consideration for the number of alternatives that can be realistically investigated with the resources available for the study. Cost-effectiveness analyses rarely involve more than four alternatives.

Describe the selected alternatives. The final step of Phase II requires that the analyst create a careful description of how each of the alternatives is functioning or would function in achieving the goal within the system under study. Several of the specific techniques used to describe the operation of alternatives at this stage include: model building, experimental design, input-output analysis, futures invention, and case studies. Whatever technique is used, the important point is that the functional characteristics of each alternative are fully understood before proceeding with the study.

> ". . . the methods of CE analysis may be ill-suited to the kinds of variables present in any study of instructional programs."

Phase III: Design Cost-Effectiveness Comparison

The purpose of this phase of the analysis is to design the specific form of the cost-effectiveness comparison itself. There are two major components to be considered: criteria and the analytical model.

Define criteria. A *criterion* is a particular property or characteristic of something which is chosen for making a decision or judgment about that thing. In a CE study, at least two criteria must be employed to judge the relative desirability of the alternative means to the goal. One of these criteria must reflect the resources consumed in attempting to achieve the goal while the other highlights the defining element of the goal's effective achievement. Most CE analyses, however, employ more than two criteria in structuring their comparison. Typically one or two cost criteria are identified along with up to five or more effectiveness variables. Additional criteria are sometimes specified which have little to do with either the cost or effectiveness of the goal's achievements. Such criteria are apt to reflect secondary or tertiary impacts of the alternatives or certain feasibility requirements in their operation (Lent, Note 1, Chapter 4). Some of the criteria employed in CE analyses of instructional technology have included: cost per student, cost per viewing, student achievement and attitudes, production of graduates, efficiency, and faculty receptivity.

Criteria should be selected on the basis of their relevance to the decision-maker. That is, they should reflect the specific dimensions of system performance which the decision-maker will consider, even intuitively, in making a final choice between or judgment of the alternatives. Criteria can be identified in part by reviewing the information needs and study purposes identified in Phase I. Additional criteria may be suggested by the process of choosing alternatives for the comparison. But the best way to define criteria is through direct interview with the decision-maker(s).

Design analytical model. The second component to be considered in structuring the CE comparison is the analytical model. This model provides the framework upon which the performance of the alternatives on the various cost and effectiveness criteria are to be compared. Two of the most common forms of analysis models in CE studies of instructional technology are ratio and matrix models. The ratio model produces a relatively direct and simple comparison of cost per unit output by alternative. The matrix model compares the alternative across an array of criteria with the performance of the alternatives reported in the naturally occurring units of each criterion. While the ratio approach virtually awards a cost-effectiveness "score" to each alternative, the matrix model leaves the final judgment of relative cost-effectiveness to the decision-maker.

Analytical models can range from simple to complex. They can rely upon physical or conceptual, and quantitative or qualitative techniques in their design. A good model will focus on the most relevant variables in the CE comparison and clearly communicate the results of the analysis. Traditional approaches to CE analysis have also emphasized the role of the analytical model in fixing certain variables and thereby simplifying the comparison. However, in educational settings, very few reported studies have been able to meaningfully fix

either the cost or the effectiveness sides of the analysis. (But they usually do control *time* as a variable.)

Phase IV: Determine Costs

The cost and effectiveness sides of the investigation represent almost separate substudies within the overall CE analysis and are treated here as such. The cost study begins with careful consideration of the nature of the resources required by the alternatives and the kinds of cost reports the decision-maker will find most meaningful. Cost analyses of instructional technology may categorize costs technically (by the nature of the specific objects or services being employed), economically (by the variable or invariable nature of the costs in an operating system), or by an accountancy classification (which distinguishes between capital and operational expenditures), or a financial classification (which classifies costs by contributor and distinguishes between direct and indirect costs). A thorough cost analysis will employ several of these cost classifications as relevant to the decision-maker (UNESCO, 1977).

The overall approach to the cost investigation itself is based upon the life-cycle costing concept in which the costs of an activity are identified over the design, investment and operation periods of its existence. (A companion paper in this series by Beilby will elaborate the specific methods of costing the use of instructional technology.)

Phase V: Determine Outcomes

Determining the outcomes of the operation of the alternatives, or the effectiveness side of the analysis, involves the conduct of an appropriate evaluation study. Each of the noncost criteria should be the focus of a specific substudy to determine the performance of the alternatives on that criterion. The design of these substudies will vary with the nature of the criteria, the resources available for the investigation, and the alternatives chosen for comparison. Effectiveness analyses of instructional technology are apt to employ a full range of evaluation methods in investigating the alternatives. Specific consideration of such methods is beyond the scope of this article.

Phase VI: Assemble Findings

The concluding phase in the conduct of CE analyses involves the synthesis of the cost and outcome sides of the study and the subsequent analysis of this information on an alternative-by-alternative basis. Three steps must be completed in sequence.

Assemble cost and outcome information. At this point it is time to apply information gathered through the separate cost and outcome studies to the analysis model. Depending on the nature of this model's design, it is sometimes necessary to transform the data as originally obtained into a form that will fit the model. For example, ratio models require that the numerator and denominator reflect a common meaningful cost per unit of output and thus a wealth of evaluative information must be reduced to a simple statement like cost-per-student contact hour, or cost-per-unit gain or an achievement test. No matter what kind of analysis model is used, it is important to report as much of the data (and assumptions employed in gathering it) as possible. Cost-effectiveness analyses will frequently uncover some important differences between the alternatives that were not suggested by the original set of criteria and these differences should be portrayed even if they do not fit neatly into the analysis model. The challenge facing the analyst here is the preparation of a clear report that portrays the results in an understandable and accessible manner.

Analyze information and prepare recommendations. The second step in developing the study's findings is to analyze the results across alternatives. Each alternative's performance is compared and contrasted across the variables or criteria important to the final decision. To accomplish this, various amounts of quantitative and qualitative data may need to be summarized within and between alternatives, and it is here that a good analysis model is most helpful. Findings from this comparative analysis, noting important similarities and differences between alternatives, should be reported in support of various decision alternatives and recommendations.

Consider uncertainties and test assumptions. The final step in the process of cost-effectiveness analysis is to review the design and conduct of the study to identify areas of particular weakness in its findings. This involves identifying those criteria and data with large uncertainty factors and conducting some form of sensitivity analysis to estimate how the findings would change if the study's assumptions were violated or errors made in the study's design or procedures (Quade, 1975). Sensitivity analyses are particularly important in predictive CE comparisons where much of the study has been based upon predictive models and estimation. The final report of the analysis should contain a section which specifically treats the likelihood of errors or changes in the findings and their impact on any conclusions drawn from the study.

> ". . . the process of conducting a CE analysis is seen to be only loosely linear with some phases occurring simultaneously."

Concluding Remarks

A six-phase model has been presented for the application of cost-effectiveness analysis to decisions involving the use of instructional technology. As described here, the model's activities imply a reasonably elaborate analysis effort: a more complicated effort may be required for some studies. The distinguishing characteristic of a good study is not its size or expense but its foundation in proper design decisions. Furthermore, in no case should the cost of conducting the CE analysis exceed the cost of choosing the wrong alternative.

Some mention also should be made as to the role of the instructional developer or educational technologist in the design and conduct of CE studies. The model's presentation carefully distinguishes between the roles of analyst and decision-maker, yet in practice such distinctions often disappear. Cost-effectiveness studies may be conducted with a team of cost analysts, evaluators, and instructional developers working to serve multiple decision-makers and other audiences for the findings. In other situations, however, the instructional de-

veloper may be his or her own analyst as well as the primary user of the resulting information.

Finally, at the beginning of this paper mention was made of the importance of adapting CE methods to the conditions confronting the conduct of analyses in instructional settings. Those familiar with the conduct of cost-effectiveness analyses in other areas, however, may find relatively few differences in the present model: many of the necessary modifications to specific methods have been changes more of degree than of kind. Generally, some of the requirements for conducting CE analyses have simply been relaxed (e.g., the requirement for either fixed cost or fixed effectiveness comparisons) in the interest of designing workable studies. Like many other activities in educational settings, the conduct of CE analyses of instructional technology may be as much an art as a science.

> ". . . the conduct of CE analyses of instructional technology may be as much an art as a science."

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