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ABSTRACT

In establishing a departmental cost-effectiveness model, the traditional cost-effectiveness model was discussed and equipped with a distant and deflation equation for both benefits and costs. Next, the economics of costing was examined and program costing procedures developed. Then, the model construct was described as it was structured around the 'decision-function' of the departmental administrator. Procedures were presented for its expeditious use. (Author)

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A DEPARTMENTAL COST-EFFECTIVENESS MODEL

Departmental administrators need a model framework upon which to structure and base decisions regarding the effectiveness and efficiency of departmental programs. Such a decision network is an important asset in insuring the sound and economical operation of a department. This is especially true whenever departmental administrators are considering the addition of new programs or personnel, or the contemplation of placing more emphasis on research than teaching or vice versa. The same is true even if programs or personnel are being considered for deletion. The well-established economic tool of cost-effectiveness analysis can provide an expeditious approach to solving such an array of problems.

Cost-Effectiveness Analysis for Departmental Administrators

Departmental heads or chairmen, in most situations, do not have to make every-day decisions involving millions of dollars. This still remains the province of the higher echelon of university presidents and deans. However, decisions do have to be made each year regarding, if not millions, thousands of dollars in departmental funds which will ultimately influence both specific and overall outputs of a department. An investment of departmental resources must be made before any program can become both operable and productive.

An educational investment, in the departmental setting, is the allocation of current departmental resources, which have alternative uses, to a departmental activity or program whose benefits will accrue over the future. These benefits derived from the productive efforts of a department usually take on the form of intangible goods and services. The actual cost of the investment with its resultant benefits is, economically speaking, the benefit that could have been derived by using the resources in some other activity. Marglin clarified the relationship of benefits and costs by writing:

> The meaning of costs, like the meaning of benefits, depends on the objective: Costs and benefits are simply two sides of the same coin. As benefits measure the contribution of a programme to an objective, so costs measure the extent to which activities that the programme displaces elsewhere in the economy would contribute to the objective.[1]

An educational program investment is justified if the benefits anticipated are greater than the costs. This is, of course, the focal point of the search for an optimality condition for any productive activity. It follows that cost-effectiveness analysis is simply a means of assessing the worth of educational program investments. It involves the enumeration and evaluation of all relevant costs and benefits over a period of time. For any educational investment to be selected over alternative investments, benefits should exceed costs, or as expressed mathematically, $\frac{B}{C} > 1$.

A central problem in the evaluation of educational program investments is presented by their proration over a period of time. Benefits accrue at different times as do costs once the initial program investment outlay is made. In compiling or summing of both benefits and costs, the analyst must establish rates of exchange for benefits at certain periods during their projected duration as well as for costs. These rates of exchange will be referred to as the discount rate which must be coupled with an estimated deflation rate for the same time period because of the anticipated usual decrease in monetary value.

Benefits and costs must be weighted in the present and future time periods equally. This is economically justified by two factors: (1) the opportunity cost, and (2) time preference of capital. Opportunity cost of capital means that a given program investment must be compared to alternative program investments having like opportunity for yielding deferred benefits and accumulating deferred costs. Time preference of capital means that present benefits to be derived from a program investment are preferred to future benefits of equal value from the same investment. In other words, discounting of benefits in accordance to time preference can be justified on the principle of diminishing marginal utility, that "from the point of view of the present, equal increments of benefits are less desirable, the longer the economy must wait to reap them."[2]

In order to put future benefits and costs on the same level as present benefits and costs they must be discounted and deflated in order for accurate comparison. Once future benefits and costs have been discounted and deflated to the point where decisions are being made the analyst can then speak of them in terms of the present value of benefits and costs. Thus the present value of future benefits can be defined as total future benefits of a selected program discounted and deflated to present day total benefits expressed in current or present value. If i is the interest rate of return on the given program investment, then 1 unit of resources invested there would yield 1+i units of benefit in 1 year, $(1+i)^2$ units in 2 years, and $(1+i)^t$ units in t years. Including a deflation rate in the equation would read $(1+i+r)^t$ units of benefits. The same equation must be applied to costs as well.

Thus, a benefit to cost ratio can be simply expressed as

$$\frac{B}{C} = \frac{B_{irT}}{C_{irT}}$$

where i = the discount rate, r = the deflation rate, T = summation of time cycle, B = benefits, and C = costs.

The precise operational sense in which B_{irT} and C_{irT} are expressed at present value in the equation has been given. It follows that the chosen program investment is justified against making an equal investment in that alternative only if the discounted and deflated cost C is less than the discounted and deflated value of the benefits B. If the present value of a program investment, discounted and deflated at the rate of return of an alternative course considered, falls short of the cost, it should not be undertaken when the economic factors are the sole consideration; if any investment is made in this it should be in the alternative program investment route with the greater benefit-cost ratio.[3]

It must be hypothesized here that in the above model it is possible to achieve the same benefits at each point of time throughout the life of the program investment in order to eliminate erratic and unforeseeable outcomes. The possibility of uniform outcomes is highly likely in real life situations or in actual practice as long as management remains of the same quality and no significant difference in the economy of scale of the program investment occurs.

It is possible that in some rare situations both alternative program investments being considered may have highly impressive benefit-cost ratios. In this case the opportunity cost criteria will not provide the answer. The solution to this problem depends wholly upon the available aggregate volume of resources as compared to current aggregate costs incurred coupled to the value judgment of the departmental administrator involved.

The Economics of Costing

The aim of cost-effectiveness analysis is to maximize "the present value of all benefits less that of all costs, subject to specified restraints."[4] In order to determine the effectiveness and efficiency of any departmental program, costs must be compiled and summed with the same accuracy and care that is given the compilation and summation of benefits. As in the case of benefits, a long run view must be taken in terms of time in that costs are estimated not only for the present or immediate future but also for the life of the project. All costs directly attributable to the project must be included. The costing procedure involves the formulation of estimates for the three cost areas of research and development, investment, and operating costs. The aggregate cost thus derived from the summation of the three areas must be discounted and deflated so as to obtain its present value.

R & D costs are simply those costs incurred during the planning stages of the program being analyzed. This means that all expenses incurred during the planning stages should be included in this category with the exception of sunk costs. Sunk costs, or costs expended on prior studies, are not to be included in any way in the compilation of costs for cost-effectiveness studies. Cost-effectiveness subject matter always deals with present and future costs, never costs accrued in the past.

Investment and operating costs can be defined as follows:

> Investment: Capital (one-time) costs required beyond the development phase to introduce a new capability into operational use.
>
> Operating: The annual costs required to operate and maintain a given capability for an element throughout its projected life or operational use.[5]

One approach to measuring the costs of an educational program investment is that of the costing of the economic factors of production which are required in proper proportions before a program's operation can commence or continue operations. These factors of production are simply termed the input mix. Classical economists referred to the factors of production as land, labor, capital, and entrepreneurship. The factors land and entrepreneurship are now commonly referred to respectively as material and management. If all factors of the input mix, material, labor, capital, and management are combined in their proper proportions at the right time and place in the form of a tangible educational program investment, output or benefits from the derived program will result. Naturally, optimum returns to scale would result if the factors of production could be combined in optimal proportions which should be the goal of every program investment.

The costs derived from the concerted operation of the factors of production can be simply added together and discounted and deflated for the total aggregate program cost. Functionally, the process may be represented by the discounted and deflated production function for a simple firm, which may be written as

$$C = \frac{f(\ldots + m + c + l + e)}{(1 + i + r)^t}$$

where C = total aggregate cost, f = function, m = material, l = labor, c = capital, and e = entrepreneurship or management. Research and development costs must also, of course, be included in the formula if such R & D costs are not sunk costs, or costs incurred before the investment decision is made. The discount-deflation rate is the denominator.

Such itemization of an educational program investment's costs is usual practice when departmental administrators lack economic training. And; such itemization is not incorrect. However, if economic analytical tools are to be properly utilized in the financial decision-making process, the educational administrator in the role of the economic analyst must pursue a more complex approach and consider costs from the opposite end of the production spectrum--that of output.

From the focal point of output, the three cost areas of research and development, investment, and operating costs must be estimated. Since research and development and investment costs must be incurred before the program begins operation, their costing is focused usually on the first two to four years. After this, the operating costs continue throughout the projected life and operation of the program. Thus, of the three cost areas, operating costs have the highest degree of sensitivity to program output.

Operating cost has two components, fixed and variable cost. Fixed cost may be defined as an operating cost which does not increase or decrease as the total volume of output increases or decreases in the short run period. Variable cost is that operating cost which increases or decreases as the total volume of output increases or decreases during a particular period, whether short run or long run in duration. In conventional accounting such costs are usually referred to as indirect (fixed or 'overhead') cost and direct (variable) cost.

When operating costs are considered as a function of output their sensitivity to output Q can be mathematically expressed in terms of the following cost components of total program operating cost C, with Δ being read as "the absolute change of":

Total program operating cost	$= C,\ 0<\Delta C/\Delta Q$
total fixed cost	$= F,\ 0<\Delta F/\Delta Q$
total variable cost	$= V,\ 0\leq \Delta V/\Delta Q$
Average program operating cost	$= A,\ 0<\Delta A/\Delta Q$
average fixed cost	$= \overline{F},\ 0<\Delta \overline{F}/\Delta Q$
average variable cost	$= \overline{V},\ 0\leq \Delta \overline{V}/\Delta Q$

These cost components are naturally expressed in terms of a short run period in which fixed costs retain their same accounting value. In the long run, economists view all costs as variable because the program being analyzed would have encountered a change in physical scale, thus forcing a change even in fixed cost or overhead. For cost-effectiveness studies a short run period, thus defined, could last as long as thirty or forty years, or as long as the program maintains its input mix within the confines of its original scale of operations.

The above operating cost components are related in this manner:

$$C = F + V = \sum_{i=1}^{m} F_i + \sum_{i=1}^{n} V_i;$$

$$A = \frac{C}{Q} = \overline{F} + \overline{V}$$

$$= \frac{F}{Q} + \frac{V}{Q} = \sum_{i=1}^{m} F_i/Q_i + \sum_{i=1}^{n} V_i/Q_i.$$

In order to systematically synthesize and examine the three cost areas, a cost matrix model may be devised patterned after Figure 1. As shown, the cost matrix may be constructed by arraying the cost areas into a two-dimensional field consisting of program functions and cost functions to be considered in the study. Such a cost matrix provides a checklist of the cost and system or program functions to

COST	PROGRAM FUNCT	COST FUNCTIONS					PRES. VALUE
	Modules	Capital	Mainten.	Administ.	Instruct.	Totals	
R & D	#1 . . . n					Σ . . . Σ	
	Total R & D	Σ	Σ	Σ	Σ	ΣΣ	ΣΣ
INVESTM	#1 . . . n					Σ . . . Σ	
	Total Invest.	Σ	Σ	Σ	Σ	ΣΣ	ΣΣ
OPERAT COSTS	#1 . . . n					Σ . . . Σ	
	Total Op. C.	Σ	Σ	Σ	Σ	ΣΣ	ΣΣ
Oper.	Op. C. (x) yrs	Σ	Σ	Σ	Σ	ΣΣ	ΣΣ
R&D+I	Total R & D + Investment					ΣΣ	ΣΣ
All	Total Program Cost					ΣΣ	ΣΣ

Figure 1. Cost Matrix Model.

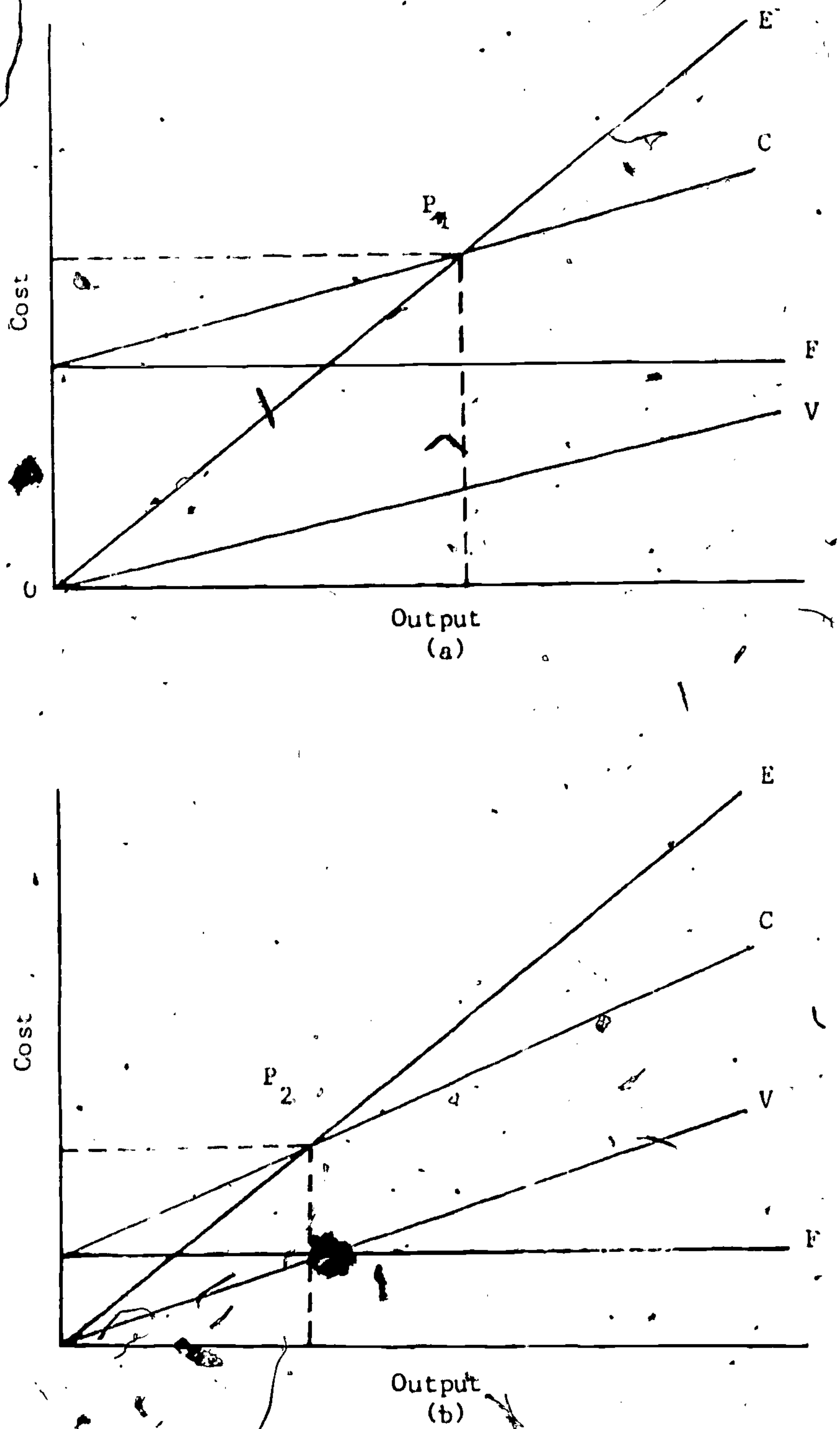

Figure 2. Break-even Charts.

be considered in a study thus providing, at a glance, aggregate and subaggregate figures identifying areas of overlap or omission derived through the costing process.

Another way of analyzing cost as a function of output is to observe the intersection of the total effectiveness or benefit curve (shown in terms of output) and the total cost curve, known as the break-even point P. A break-even analysis is of particular importance to a cost-effectiveness analysis when the ratios of the fixed cost to the variable cost are widely different among the competing alternatives. For comparison, consider two programs that have the same benefit or effectiveness curve E and also reach the same total program cost C. The only difference in the two programs is the ratio of fixed (investment) cost F to variable (operating) cost V, as shown in Figure 2.a and b.

Even though the two programs may have the same benefit or effectiveness curve and the same total cost at the same output level, their break-even points may be widely different. Programs with the higher fixed cost therefore would be relatively less desirable than programs having the higher variable cost.

A financing decision may have to be made between renting or purchasing equipment. The break-even charts can be used to resolve this problem also. The curves in Figure 2.a and b would maintain the same appearance. The break-even chart in (a) would represent the purchase alternative with its high fixed cost/low variable cost; (b) would represent the rental alternative with the low fixed cost/

high variable cost.

Costing, as well as the quantification and measurement of benefits, remains an art and cannot be considered a science. Therefore, there are no set rules or procedures that can be followed in all cases which can insure the derivation of reliable cost estimates. Only general guidelines can be advanced which offer basic ingredients or elements which if included in a study should provide a basis for successful costing.

The following statements are brief costing guidelines that should be observed in all cost estimates for cost-effectiveness studies.[6] They should not be construed to be totally inclusive in content because unique costing problems may arise in connection with some analyses.

1. All significant costs that might affect the choice of alternatives should be included in the analysis. All phases of the life cycle of a program should be considered for inclusion--research and development, investment, and operating costs. Normally, studies will need to include costs for all three phases to make certain that the complete costs' impacts are presented.

2. Both variable and fixed operating costs should be considered a part of the total program cost and should be included in the study.

3. Sunk costs (i. e., costs which can reasonably be assumed to have been expended prior to the beginning of the time period examined in the study) are irrelevant and should be excluded.

4. In order to permit proper evaluation and understanding of

the work, each study should be fully documented as to the source, techniques, cost-estimating relationships and assumptions used to develop the costs. Preferably, an individual cost matrix sheet (see Figure 1) should also be provided on each program considered in the analysis.

5. Costs for cost-effectiveness studies should be discounted and deflated.

6. The exact quantity of any proposed hardware that would eventually be procured can seldom be completely resolved at the time of the study. It is thus desirable that the cost information supplied permit estimation of costs at various quantities within a reasonable range of possibility, as excursions from the cases directly examined in the study might prove necessary.

7. The level of detail to which programs should be broken down and for which costs are to be displayed depends upon the nature and depth of the individual study. The originator of the study should specify in advance the level of detail needed.

The Basic Departmental Cost-Effectiveness Model Construct

As conceived in this model, a university department exists in order to provide programs for its clients, the students. In turn, the sum or aggregation of the several programs of a department constitute what is usually termed, its curriculum. The cost-effectiveness model, as constructed, is built with the intent of evaluating only programs. However, with only a few modifications a department's curriculum could be evaluated via the same model construct. In an economic context, a department's resources can be classified as faculty (including full-time researchers, part-time faculty, and part-time teaching-research assistants), administrators (usually only one head or chairman), and capital (both working and fixed). These departmental resources correspond to the economic factors of production and are referred to as the input mix. Likewise, the students, either as graduates of a department's programs or as students who have completed certificate programs administered by the department, are considered the product or output of a department's programs.[7]

This departmental cost-effectiveness model for program evaluation is designed with the decision-maker in mind. The departmental decision-maker, usually the department head, exercises the function of choosing among alternative courses of action in order to achieve an optimal program mix (curriculum) which in turn should produce an optimal output (graduates). This primal function of the department head will be referred to as the 'decision-function'.

The problem of this cost-effectiveness analysis lies in the estimation of the decision function. The decision function can be expressed mathematically as

$$D\left[\frac{f(X,Y)}{C}\right]$$

where X is that portion of the output of the departmental program that can be expressed in monetary terms, i. e., elements that are commensurable in monetary units with costs. Y is that portion of departmental output which cannot be measured in monetary terms. C represents the aggregate cost of the program's input mix. D represents the decision of the department head while f represents the function.

The decision function of a department's administrator is bounded by two objectives in a cost-effectiveness study. The first objective deals with program output, the other with program input.

1. Maximize present and terminal value. The objective is to maximize the value of benefits (outputs) of the department's program being considered. The benefits are those that are both current and future in attainment.

2. Minimize present and terminal cost. The objective is to minimize the value of inputs (costs of resources) of the department's program. The costs accrue in both present and future periods of the program's operation.

The output of a department's program can be analyzed in two phases:

Phase One. The commensurable part, is derived by measuring the number of successful completions of degree and/or certificate plans by students enrolled in the program and expressing this figure in monetary units which is then compared to program costs.

Phase Two. The incommensurable part, is derived by using the raw datum of the number of successful completions of the degree or certificate plans related to the program and comparing this figure to costs.

In the first phase, the number of completions of degree plans and certificate programs can be expressed in monetary terms by capitalizing the expected lifetime income earned by all students who finish the program. This figure so derived must then be compared to total costs of the input mix or resources used in producing the output. The costing procedure was given in the above section. The effectiveness and efficiency of the program's output can be determined via these commensurable figures.

The formula for deriving X or the commensurable part of the decision function is as follows:

$$X = \sum_{t=1}^{m} \frac{I_{st}}{(1+i+r)^{m}} - \sum_{t=1}^{n} \frac{I_{ft}}{(1+i+r)^{m}}$$

where

I_s = starting annual salary plus incremental raises

I_f = annual income foregone

i = annual discount rate

r = annual deflation rate

m = expected worklife

n = years of study

In the second phase, three simple steps can be followed ~~which~~ can illustrate program outputs in graphical form. In step one, a graph can be drawn showing the number of faculty members connected with the program on the abscissa or horizontal axis and the number of graduates of the program on the ordinate or vertical axis. In step two, still using the number of faculty members as the denominator, the costs of the program should be placed on the ordinate axis. In step three, with information taken from the first two graphs, a third graph can be established which combines the costs on the ordinate axis with the number of program graduates on the abscissa.

When all program alternatives with their costs and outputs are plotted on each of the above graphs in the same order as the other programs, the optimal envelope of programs can be spotted at a glance simply by observing the relationship of the program curves to one another.

In like manner, once the commensurable phase has been completed, a simple ratio graph can be constructed which illustrates the relationship of the ratios of the various programs to one another. At the same time, maximum effectiveness and minimum cost boundaries can be drawn on the graph surface illustrating the lower and upper bounds of efficiency.

The following statements are brief guidelines that should be observed in all departmental program cost-effectiveness studies. They should not be construed to be totally inclusive in content because unique problems may arise in connection with some analyses.

1. Costing guidelines as given in the above section should be followed in compiling costs.

2. In order to permit proper evaluation and understanding of the program, each study should be fully documented as to the source, techniques, output-estimating relationships and assumptions used to quantify or enumerate program outputs.

3. Outputs or benefits for cost-effectiveness studies should be [illegible]anced and deflated.

4. If possible, benefits and costs should be compared in both

commensurable and incommensurable situations in order to provide a check on program evaluation outcomes.

5. In any study, the entire analysis should be closely structured in light of the decision-function and its two accompanying objectives of minimizing total program costs and maximizing total program outputs.

6. In order to avoid bias in a study of alternative programs, select only similar programs for comparison. Diverse programs that have no input or output data similarities have no direct basis for comparison in a cost-effectiveness study.

7. Cost-effectiveness studies are not to be construed to be substitutes for the value-judgment of the departmental administrator; such studies are only supplements to value judgment.

Summary

In establishing a departmental cost-effectiveness model, the traditional model was discussed and equipped with a discount and deflation equation for both benefits and costs. Next, the economics of costing was examined and program costing procedures developed. Then, the model construct was described as it was structured around the 'decision-function' of the departmental administrator. Procedures were presented for its expeditious use.

Notes

[1]Stephen A. Marglin, Public Investment Criteria: Benefit-Cost Analysis for Planned Economic Growth. Cambridge, Mass.: The M. I. T. Press, 1967, p. 45.

[2]Ibid., p. 47.

[3]A Clarification note on B-C or B/C analysis. By now the reader may have surmised that benefits and costs relationships can be analyzed either through subtraction or division. In subtraction, if costs are subtracted from benefits, net benefits (±) would be the remainder. In division, costs are divided into benefits producing a ratio. In the majority of cases, the ratio of benefits to costs is preferred over the remainder of net benefits because ratios give smaller and easier to compare figures which are weighted in terms of each alternative investment.

[4]A. R. Prest and R. Turvey, "Cost-Benefit Analysis: A Survey," The Economic Journal, December, 1965, p. 686.

[5]B. D. Bradley, et. al., A New Cost Model to Support Air Force Long-Range Planning. P-3133. Santa Monica, Cal.: The Rand Corp., May, 1965, p. 10.

[6]Several items for the following guidelines were taken from Costing Guidelines for Department of Defense Cost-Effectiveness Studies. Washington, D. C.: Office of the Assistant Secretary of Defense, Resource Analysis Division, May, 1966.

[7]In examining research from the context of a teaching program's

output, three points can be made: 1. Any research resulting from the program's usual operation is peripheral in nature and is an indirect result of said program's operation. 2. Departmental research is, in most cases, conducted under separate auspices from a teaching program's course content. 3. If a program specifically has research efforts formally described in its plan, any research output attributed directly to that program should be counted as part of the program output; in turn, such research output must also be considered in compiling the program's input or costs. In the third instance, linear programming can be used in allocating program time and resources between teaching activities and research.

As a further note, students should be considered a part of the input mix if they are included as a cost in the departmental budget. For example, in a work-study program many students may receive part of their wages from departmental funds and thus must be so counted in costing a department's resources.