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ABSTRACT

Because each country and each instructional option provides a speical case requiring its own particular analysis, the purpose of this paper is not to provide a cost-effectiveness or cost-benefit analysis of new instructional media, but rather to provide improved information concerning costs of instructional television and radio so that the specific analyses which are performed will be improved. Major sections of the paper describe an improved method of cost analysis, prior cost experiences with the new media, and cost functions for instructional radio and television. Appendixes provide more detail on costs of printed material, computer managed instruction, and instruction technology, as well as supplementary table for El Salvador and the Ivory Coast. (RH)

THE COST OF INSTRUCTIONAL RADIO AND TELEVISION FOR DEVELOPING COUNTRIES

by

Dean Jamison
with Steven Klees

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THE COST OF INSTRUCTIONAL RADIO AND TELEVISION FOR DEVELOPING COUNTRIES*

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I. INTRODUCTION: THE ROLE OF COST ANALYSIS

Budgets constrain choices. They are not the only constraints; law, custom, tradition, political alignments, and inertia all serve to limit further a decision-maker's options. Nevertheless, budgets remain a central constraint. With his budget a Minister of Education can buy teachers, books, schoolhouses, radio sets, and the other inputs he needs to run his school system. The amount of each input that it is feasible for him to buy depends on the costs of the inputs and the level of his budget; his feasible alternatives constitute the set of all possible combinations of inputs whose total cost falls within the budget. In order to know which potential alternatives are feasible and which are not, the Minister must assemble information on input costs. Our purpose in this paper is to assist in that task by bringing together available information on the cost of instructional radio and television and by developing a methodology for analyzing that information. To a lesser extent we discuss the costs of other new media.

Obtaining costs in order to determine the set of economically feasible alternatives is the first step in educational planning, but it is only a first step. The Minister of Education must also obtain

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available information concerning the linkage between educational inputs and educational outputs and the linkage between educational outputs and economic and social outcomes.

Cost-effectiveness analysis uses knowledge concerning the first linkage, between educational inputs and outputs, to help ascertain which of the feasible alternatives will result in the 'maximum' educational output. (As educational output is multidimensional, e.g., number of graduates of each level per year, the term 'maximum' output is used here to mean an output that can be increased on no one dimension without either being decreased on another or violating the budget constraint.) Cost-effectiveness analysis, then, deals with the problem of how to get the most in terms of educational output from the funds available to the educational system.[1] It constitutes the second step in educational planning.

The third step in educational planning deals with the relationship between the outputs of the educational system and various economic and social goals. Are educated individuals more economically productive? less inclined to crime? better citizens? If so, which types of education contribute most to these goals? Answers to these questions would assist the Minister of Education and the Central Planning Agency in ascertaining how much should be spent on education altogether and how that amount should be distributed across various types of education. In the terms of the preceding paragraph these answers would help enable the Minister to decide which of the maximum levels of output is most desirable for any given budget and to decide on an appropriate budget level. Cost-benefit analysis is the term economists use to describe this third step of educational planning, and economic research in

[1] Jamison [1972] develops one methodology for cost-effectiveness analysis of schooling in developing countries and provides references to the literature. Use of the term 'cost-effectiveness analysis' to describe the activities involved in modeling input-output relations in education is misleading to the extent that it implies the task to be one for economists. Experts in educational psychology, media research, statistics, and organizational theory play a more central role.

education has focused on measurement of benefits for improving cost-benefit analyses.[2]

Our purpose in this paper, provision of improved information concerning the costs of instructional television and radio, can be viewed as an attempt to improve cost-effectiveness and cost-benefit analyses in education. This is the role of cost analysis. We wish to make explicit, however, that our paper in no way attempts to provide a cost-effectiveness or cost-benefit analysis of the extent to which these new media should be used. Such analyses need be done in the context of a particular country's price system, non-budgetary constraints, overall economic situation, and development objectives.

This paper has three major parts. The first of these, Section II, describes the methodology we use in our cost analysis. Different methodologies of analysis can lead to different results, and for this reason it is desirable to be both clear about the methods one is using and correct in their application. We feel the methods we use in treating capital costs to be more nearly correct than those used in previous analyses of the costs of instructional radio and television; we explain these methods fully, and this will require the reader's patience with an occasional equation.

There exist two distinct ways of obtaining the empirical information required for use with one's methodology. The first is to use data from ongoing or planned projects to ascertain what cost experiences others have had. The second is to formulate cost functions from component costs that are obtained, for example, from manufacturers' catalogs. The second and third of the three major parts of this paper develop each of these approaches. In Section III we use available information to

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[2] Psacharopoulis [1972] reviews an extensive literature that assesses the economic benefits of various forms of education (and computes rates-of-return) by attempting to disentangle the influence of education from other determinants of individuals' incomes. Griliches [1970] surveys and synthesizes a much smaller literature that examines the effect of education on worker productivity and national economic growth.

present, in as comparable a form as we can, the cost experiences of a number of ongoing and planned projects. In Section IV we develop cost functions for instructional radio and television systems from component cost information, and in a closing section we draw together our conclusions. Three appendices deal briefly with the cost of printed material, the cost and potential role of computer managed instruction, and the 'opportunity cost' of instructional radio and television.

II. METHODOLOGY OF THE COST ANALYSIS

Our purpose in this paper is to examine the costs of several inputs[3] to the educational process. There is by now a reasonably extensive literature concerning educational costs,[4] but the methodologies of that literature differ from what is required for adequate treatment of the cost of instructional technologies. The reason appears to be, that with the exception of building costs, concerning which a decision-maker usually has little choice, most educational costs are recurrent. Decisions to utilize a technology, on the other hand, entail acceptance of a commitment to pay now and reap the benefits later; for this reason an adequate analysis of the cost of instructional radio and television must grapple directly with the problem of the temporal structure of cost and utilization.

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[3]Most discussion of cost in economics centers around how the cost of output varies with its quantity under the assumption that the producer of the output is economically efficient -- see, for example, Henderson and Quandt [1958, pp. 55-62]. The concepts of total, average, and marginal cost that are usually used to describe output cost can also be used to describe input costs; usually, however, the cost of an input is simply assumed to equal the quantity utilized times its unit price. This simple model of input costs is inadequate for our purposes. Walsh [1970, Chapter 22] engagingly synopsizes the history of economists' usage of the term 'cost,' and provides a clear statement of modern views.

[4]Perhaps the most valuable discussion of educational costs is a recent book of Coombs and Hallak [1972]; this is one in a series of studies, sponsored by UNESCO's International Institute for Educational Planning, that also includes Vaizey and Chesswas [1967] and Hallak [1969]. Other general discussions of educational costs include Bowman [1966], Edding [1966], and Thomas [1971, Chapter 3]. Vaizey, Norris, and Sheehan [1972, Part Six] treat teacher costs in some detail, and Schultz [1971, Chapters 6 and 7] discusses the important and occasionally overlooked cost of students' time. Previous discussions of educational technology costs appear in Schramm, Coombs, Kahnert, and Lyle [1967, Chapter 4 and the accompanying volumes of case studies], General Learning Corporation [1968], and Hayman and Levin [1973].

In this section we describe the methodology we use to handle this problem of cost and utilization occurring at different points in time. Our methods draw on the standard economic theory of intertemporal choice; but, as often occurs when applying economic theory, minor modifications are required to deal with the problem at hand. We begin by describing cost functions and their properties, then describe methods of annualizing capital costs. Finally, we point out that utilization of annualized capital costs can understate the true costs of utilizing an instructional technology, and introduce a method for incorporating the time structure of utilization into the analysis.

A. Cost Functions and Their Properties

We begin this subsection by defining the concepts of total cost, average (or unit) cost, and marginal cost; we then examine the special case in which it is appropriate to separate costs into fixed costs and variable costs. We conclude by discussing the situation in which there are multiple inputs to the cost function.

Total, average, and marginal cost. It is useful to think of costs as functions rather than numbers; a total cost function for an input gives the total cost required to finance an input as a function of the amount of the input required. To take an example, let

$$\text{Total Cost} = TC = TC(N),$$

where $TC(N)$ is the total cost required to provide an input of instructional television to N students.

The average cost function (or, equivalently, unit cost function) is defined to equal the total cost cost divided by the number of units of the input provided:

$$\text{Average Cost} = AC(N) = TC(N)/N\ .$$

Just as the total cost depends on N , so may the average cost.

The <u>marginal cost function</u> gives the additional cost of providing one more unit of input (i.e., in this example, of providing instructional television to one more student) as a function of the number of units already provided. Stated slightly more precisely, the marginal cost function is the derivative of the total cost function:

$$\text{Marginal Cost} = MC(N) = dTC(N)/dN \ .$$

Again, it is important to keep in mind that the marginal cost will in general be a function of N .

<u>Fixed and variable costs</u>. When the total cost function can be approximated by the simple and convenient linear form,

$$TC(N) = F + VN \ , \qquad (1)$$

it becomes possible to separate costs into fixed costs and variable costs. In this example, F would be the <u>fixed cost</u> because the value of cost contributed by the first term on the right hand side is independent of N ; V is the <u>variable cost</u> per unit of input because the value of total cost contributed by the second term on the right hand side varies directly with N . When the total cost function is linear, as in equation 1, the average cost is simply equal to the fixed cost divided by N plus the variable cost ($AC(N) = F/N + V$); the marginal cost is equal to V . Thus the average cost declines as N increases (by spreading the fixed cost over more units) until, when N is very large, the average cost is close to the marginal cost.

Equation 1 is a reasonably good approximation to the cost behavior of educational technology systems. Program preparation and transmission tend to be fixed independently of the number of students using the system. Reception costs, on the other hand, tend to vary directly with the number of students. The analysis in Section III of the cost behavior of planned and ongoing projects relies heavily on the total cost model of equation 1 that separates costs into fixed and variable components.

An occasional source of confusion, even among economists,[5] is between fixed costs and capital costs. There can be fixed costs that are recurrent; an example is the electric power required to operate a television transmitter. Likewise there can be capital costs that are variable; an example is the receiver component of reception costs. Thus the concepts of fixed costs and capital costs are distinct though it is often true that major capital expenditures are associated with substantial fixed costs.

Multiple inputs to the cost function. In the preceding subsections we have assumed that the total cost of providing instructional radio or television depended on only a single variable, the number of students reached. This is a reasonable approach in circumstances where one can assume other potentially relevant variables to be fixed. Often, however, particularly in planning situations, it is important to consider explicitly the other variables. The input one wishes to cost is not just instructional television for N students; it is, instead, instructional television for h hours per year for N students spread over a geographical region of x square miles. More variables could be added.

While treatment of multiple inputs involves some additional complication, the basic concepts introduced so far change but little. Total cost is now a function of several variables; in our new example,

$$TC = TC(N,h,x) .$$

The marginal costs become the amount total cost changes for a unit change in each of the determining variables; in this 3 variable example we have 3 marginal costs defined mathematically by partial derivatives as follows:

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[5] See, for example, Coombs and Hallak [1972, p. 156].

$$MC_N = \frac{\partial TC}{\partial N} \; ; \; MC_h = \frac{\partial TC}{\partial h} \; ; \; \text{and} \; MC_x = \frac{\partial TC}{\partial x} \; .$$

Each of these partial derivatives can be a function of N, h, and x . Likewise there are a number of average costs -- the cost per student, TC/N , the cost per hour of presentation, TC/h , etc. In addition, however, one may wish to consider composite averages, for example the cost per student per hour. That cost would be TC/Nh .

Aside from potential practical complications, then, there is small conceptual difficulty in going from consideration of a single determinant to multiple determinants of cost. In the remainder of this paper we will generally assume single determinants of cost in our analysis of the costs of ongoing projects (Section III)[6] and multiple determinants in our development of general cost equations (Section IV); this reflects the utility of considering multiple determinants in the planning process. We turn now to more detailed consideration of capital costs.

B. Treatment of Time I: Annualization of Capital Costs

A capital cost is one that is incurred to purchase a piece of equipment that will have a useful lifetime that extends beyond the time of purchase. Recurrent costs, on the other hand, are incurred for goods or services that are used up as they are bought. The principal cost of schools is the recurrent cost of teachers' time;

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[6] In order to let the number of students in the system be the sole determining variable we occasionally will find it convenient to let the values of fixed and variable cost, F and V , depend on aspects of the system that are assumed to remain unchanged. F will depend, among other things, on the number of grade levels the students to be reached are in, as well as the geographical area over which they are spread. Receiver costs per student and hence V will depend on class size. If the situation warrants the assumption that these other variables will change little, it becomes possible to use the convenient formulation of equation 1: TC(N) = F + VN .

since teachers are paid while they provide their service, the useful lifetime of what is actually purchased simply coincides with the pay period. (In this example we neglect the human capital forming aspect of teacher training colleges.) The cost of a pencil would seem to be a capital cost since, depending on one's penchant for writing, it could last for several months. In fact pencils are treated as recurrent costs for the reason that its expected lifetime is less than the accounting period (usually one year) of school systems. The line between capital and recurrent costs is, then, usually drawn at one year; if the useful lifetime of a piece of equipment is greater than that, its cost is usually treated as a capital cost. Coombs and Hallak [1972, Chapter 9] point out that school systems often adhere only loosely to this one year convention and provide a valuable practical discussion of how to plan for school building and facilities costs.

How does one construct the cost functions discussed in the preceding subsection if capital costs are present? Let us say that a school system buys a radio transmitter and 6000 receivers in year 1 for a total cost of $220,000. It would clearly be inappropriate to include the entire $220,000 as a year 1 cost in attempting to determine the unit cost of radio in year 1; likewise it would be inappropriate, in computing year 3 unit costs, to consider the use of transmitter and receivers as free. In order to construct a useful cost function it is necessary to annualize (unfortunate verb) the expenditure on capital equipment.

Two variables are important in annualizing expenditures on capital equipment. The first of these is the lifetime of the equipment; if the equipment lasts n years a fraction, on the average equal to $1/n$, of its cost should be charged to each year. This is a depreciation cost.

The second variable that is important in annualizing capital expenditures is the social discount rate. The social discount rate reflects the value judgment concerning the cost to society of withdrawing resources from consumption now in order to have more consumption later. It is represented as an interest rate because in an important sense the 'cost' of capital is the interest charge that must be paid for its use. One way of obtaining an approximation for an appropriate value for the social discount rate is to examine the private cost of capital. If a country has invested $220,000 in radio facilities, the capital thereby committed cannot be used elsewhere, e.g., it cannot be used to construct a bicycle factory or fertilizer plant. To see the importance of this let us assume that the lifetime, n , of the $220,000 worth of radio equipment is 10 years and that the country could, if it chose, rent the equipment for $22,000 per year instead of buying it. Whether the country rents or buys, then, over the 10 year period it will spend $220,000 on equipment. But it is obvious that the country would be foolish to buy under these circumstances for the simple reason that if it rented the radio equipment it could put the $220,000 in a savings bank in Switzerland (or in a fertilizer plant) and collect interest (or profits from the sale of fertilizer). Of course for most of the time the country would collect interest on only a part of the $220,000 if it were paying the rent out of this account; nevertheless, if it were receiving 7.5% interest, there would be $132,560 in the bank at the end of the ten years.

As this example has indicated there is a cost (interest charge) involved in having capital tied up in a project, and this cost is measured, to some extent, by the potential rate of return to capital elsewhere in the economy.[7] The total amount of this cost depends, of

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[7]The issues involved in determining a value for the social rate of discount are actually rather complex and involve consideration of reinvestment of returns as opposed to consumption of them. The productivity of capital in an economy is a measure of what must be given up to finance a project; there remains the problem of comparing net costs and benefits that occur at different points in time. Dasgupta, Sen, and Marglin [1972, Chapters 13 and 14] review these issues and argue forcibly that a discount rate to make net returns at different points in time comparable reflects a social value judgment. They argue, therefore, that the policy analyst should use a number of social discount rates in order to exhibit clearly the sensitivity of the results to the values chosen. This we do, using annual discount rates of 0%, 7.5%, and 15%.

course, on the amount of capital that is tied up; if the value of the capital in a project is depreciating, as it must be as its lifetime draws to a close, then the amount of capital tied up decreases from year to year. It is thus inappropriate in annualizing capital costs to depreciate the value of initial capital by $1/n$ and add a capital charge equal to the social rate of discount times the initial value of the capital.[8] One must take into account the changing value of the capital over the project life.

If we take this changing value into account and are given an initial cost, C, for an item of capital equipment, its lifetime, n, and the social rate of discount, r, the annualized cost of capital is given by $a(r, n)C$, where the annualization factor, $a(r, n)$, is given by equation 2:

$$a(r, n) = [r(1 + r)^n]/[(1 + r)^n - 1] . \qquad (2)$$

The derivation of equation 2 would lead us astray from our main purposes; we refer the interested reader to the complete account in Kemeny, Schleifer, Snell, and Thompson [1962, Chapter VI]. In our television example we assumed a value of C equal to $220,000 and a lifetime of 10 years; if we assume a social discount rate of 7.5%, we have the following:

$$\text{annualized cost} = [.075(1.075)^{10}]/[(1.075)^{10} - 1] \times 220{,}000 .$$

[8] Unfortunately this is the procedure used by the economists involved in the IIEP [1967] case studies of the New Educational Media in Action and by Carnoy [unpublished]. Their approach overstates the cost of the media, though for the IIEP case studies, such a low discount rate is used (about 3%) that the mistake is partially counterbalanced. Speagle [1972, p. 228], in his assessment of the cost of instructional television in El Salvador, concluded that '... the inclusion of interest charges would not have made much practical difference for the usefulness of this study as a policy instrument while opening a Pandora's Box of theoretical arguments, imputations, and adjustments.' We feel that inclusion of interest charges does have practical relevance for understanding the El Salvador experience, and we indicate its magnitude in Section III.

This is equal to $32,051 per year. Table II.1 shows a(r, n) for a number of values of r and n . When r is equal to zero,

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Insert Table II.1 about here

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equation 2 breaks down and a(r, n) simply equals 1/n .

If all capital costs are annualized in the way suggested here it becomes possible to compute the annualized values of F and V for the total cost function of equation 1 (or to compute the parameters of a more complicated cost function). If assessment of the parameters is all that is desired -- and that, indeed, is much of what one needs to know -- no further theoretical work is necessary. But if one wishes to compute, say, an average cost one needs in addition a value for N , the number of students using the system. Not only does the incidence of cost vary with time but so does N ; more specifically, in contrast to cost, N tend to be low at the outset and large later. Our purpose in the next subsection is to examine the effects on unit costs of considering explicitly the time structure of utilization.

C. Treatment of Time II: Student Utilization over Time

Our purpose in this subsection is to develop a method for displaying the unit costs of an educational investment that takes explicit account of the time structure of utilization as well as of costs and that allows examination of costs from a number of time perspectives. The question of time perspective is important. Before undertaking a project a Minister of Education faces the substantial investment costs required to buy equipment, develop programs, and shake down the operations; 3 or 4 years later these costs will have been incurred to a substantial extent and the cost picture facing the Minister is very different indeed. His initial capital costs are sunk, and except

Table II.1: Values of the Annualization Factor a(r, n)

n	r = 0	7.5%	15%
1	1.00	1.00	1.00
2	.500	.557	.615
3	.333	.385	.438
4	.250	.299	.350
5	.200	.247	.298
6	.167	.213	.264
7	.143	.189	.240
8	.125	.171	.223
9	.111	.157	.210
10	.100	.146	.199
11	.091	.137	.191
12	.083	.129	.184
13	.077	.123	.179
14	.071	.118	.175
15	.067	.113	.171

for the potential (slight) resale value of his equipment, there is nothing to be recovered from abandoning the project.[9] What is desirable, then, is a method for displaying costs from the perspective of a decision maker prior to commitment to a project, 1 year into the project, 2 years into the project, etc.

It is also desirable to consider various time horizons for the decision-maker. What will the average costs have been if the project is abandoned after 3 years? Allowed to run for 15 years? This suggests the value of looking at average costs[10] as seen from year i of the project with a horizon through year j. We will denote the "average cost from i to j" by the symbol AC_{ij} and define it to mean total expenditures on the project between years i and j divided by total usage of the project (number of students or student-hours of use), with both costs and usage discounted back to year i by the social rate of discount, r. Let C_i be equal to the total amount spent on the project in year i, including fixed and variable costs, and capital and recurrent costs. Let N_i be the total number of

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[9] It may nonetheless be wise to abandon the project -- if, to be specific, still to be incurred costs exceed the benefits of continuing.

[10] One could also look at total and marginal costs; in our treatment here we focus on average costs because we feel them to be useful in aiding the decision-maker's intuition, prior to project commitment. Expansion decisions should, of course, rely on marginal costs. The concept AC_{ij} being developed here is implicitly based on the concept of a vector valued total cost function, where the dependent variable is a vector giving total cost in each time period. The independent variables, too, become vectors potentially assuming different values at different times.

student hours (this is the utilization measure we shall generally use) of usage of the project in year i . Then AC_{ij} is given by:[11]

$$AC_{ij} = \frac{\sum_{k=i}^{j} C_k / (1+r)^{k-i}}{\sum_{k=i}^{j} N_k / (1+r)^{k-i}} . \qquad (3)$$

A decision-maker at the beginning of i can in no way influence expenditures or student usage before time i so that costs and benefits incurred up to that time are for his decision irrelevant and are not incorporated into AC_{ij} . What AC_{ij} tells him is the cost per student of continuing the project through year j , under the assumption that year j will be the final year of the project. By examining how AC_{ij} behaves as j varies the decision-maker can obtain a feel for how long the project must continue for unit costs to fall to the point of making the continuation worthwhile. When the decision-maker is considering whether the project should be undertaken at all, he should let i=1 ; i.e., he should compute AC_{1j} for various values of j . In these considerations ideally the decision-maker should base decisions on the value of j corresponding to the end of the project for his discounting of the future is already taken into account by equation 3. In the real world, however, there is a possibility that the project be terminated prior to its planned end, and it is thus

[11]It may aid in understanding equation 3 to explain the concept of the present value of a cost. Assume that a cost of $4000 is to be incurred 8 years from now. The <u>present value</u> of that cost is the amount that would have to be put aside now, at interest, to be able to pay the $4000 in 8 years. If the interest rate is 6% and we put aside an amount z now, in 8 years we will have $z\ (1.06)^8$ assuming annual compounding. If we are to have $4000 at the end of the eighth year, $z\ (1.06)^8 = \$4000$, or $z = \$4000/(1.06)^8$. z is the present value of $4000 8 years from now when the interest rate is 6%; its numerical value is $2509.65. The numerator of equation 3 is the present value (viewed from the perspective of year i as the "present") of all costs incurred between years i and j . The denominator is the present value of student hours of utilization.

of value to the decision-maker to see how many years it takes AC_{1j} to drop to a reasonable value and how many years more before it stabilizes to an asymptotic level. Clearly projections such as these rest on planned costs and utilization rates.

At this point it may be of value to include a brief textual example to illustrate the concepts; in Section III we will apply this method of analysis to cost data from El Salvador and the Ivory Coast. In our example we assume a project life of 6 years. In year 1 a $1000 investment is made and no students use the system. In years 2 through 6 costs of $250 per year are incurred and 50 students per year use the system. Table II.2 shows C_i and N_i for each of the 6 years of the project and Table II.3 shows AC_{ij} under the assumption that the social rate of discount is 7.5%.

Insert Tables II.2 and II.3 about here

We should make a few comments about the values of AC_{ij} in Table II.3. First, there are no entries in the lower left; this is natural because the horizon (j) must be at least as far into the future as the time from which it is viewed (i). Second, for values of i greater than or equal to 2, AC_{ij} is uniformly $5.00 (= $250/50). This is because the only capital cost is incurred in period 1 and from period 2 on future costs and utilization are discounted to the present in the same proportion. (It is natural, once the capital cost is incurred, that the decision maker view the unit cost as $5.00 from that time on.) Third, AC_{11} is infinite; because costs have been incurred and no students have used the system the unit cost becomes indefinitely large. Fourth, in this example the interesting numbers occur in row 1. As the time recedes further into the future, the unit costs are spread over more students reducing AC_{1j}; if the project had a long enough life, AC_{1j} would become closer and closer to $5.00 as j got larger. AC_{1j} shows how the average cost behavior

Table II.2: Example Cost and Student Usage

N Year	C_i	N_i
1	$1000	0
2	250	50
3	250	50
4	250	50
5	250	50
6	250	50

Table II.3: Example Values of AC_{ij}

Year i	horizon year, j 1	2	3	4	5	6
1	∞	26.46	16.14	12.69	10.97	9.95
2		5.00	5.00	5.00	5.00	5.00
3			5.00	5.00	5.00	5.00
4				5.00	5.00	5.00
5					5.00	5.00
6						5.00

of the project looks prior to its initiation, and the value of AC_{1j} (for j near the project lifetime value) should be important in determining whether to proceed.

D. A Summing Up of Methodological Considerations

We began this section by defining a total cost function and the related concepts of average cost function and marginal cost function. We then examined the special case when costs can be separated into fixed and variable. To apply these concepts to real world data concerning instructional radio and television projects it is necessary to annualize capital costs in a way that appropriately accounts for depreciation and the social rate of discount. Section II.B described the method for doing this and observed that most prior treatments of educational technology costs failed to annualize capital costs properly. The annualized capital costs, plus values for recurrent costs, give the parameters F (fixed) and V (variable) in the simplified total cost function $TC(N) = F + VN$.

To obtain average or unit costs one also needs a value of N. In any one year, say year j, the appropriate average cost for that year is $F/N_j + V$, where N_j is the number of students using the system in year j. Since N is typically zero or very low for the first few years of a project, then rises, use of a (high) value of N from late in the project to compute average costs is somewhat misleading. It will tend to understate the average costs that have actually been incurred over the life of the project, even though the estimated values of F and V might give an adequate picture of the cost function.

To avoid this difficulty we suggested a method in Section II.C for displaying the 'average cost from i to j,' that is, the total of costs incurred from time i through time j divided by total usage in that time interval. We used the symbol AC_{ij} to denote the average cost from i to j when costs and usage are properly discounted. Use of AC_{ij} gives a more accurate picture of average costs than does simply inserting a value of N from late in the life of the project into the average cost equation. The AC_{ij}s also enable a decision-maker to see clearly the structure of his future unit costs after he has committed himself to capital acquisitions; this annualized costs are unable to do. The additional usefulness of the AC_{ij}'s comes with a cost, namely, much more information is required to obtain them. One needs a detailed time pattern of expenditure and utilization (either actual or projected) to compute values of AC_{ij}.

Finally in summing up we should note that though we have been discussing levels of costs we have not yet touched on the issue of who bears them. Frequently at least part of a developing country's expenses for an educational technology project are borne through grants or soft loans; if so, it is important to attempt to examine how the costs look from the point of view of the country, as well as in total. We are able to do this reasonably well for El Salvador.

III. PRIOR COST EXPERIENCE WITH THE NEW MEDIA

In this section we apply the methodology developed in the preceding section to analysis of the cost experience of 8 specific projects. Five of these are television projects -- in Colombia, American Samoa, El Salvador, Mexico, and the Ivory Coast -- and three of them are radio -- in Thailand, Mexico, and Indonesia. All these projects utilize the medium within a school setting for elementary and secondary education;[12] all but 2 of them have been underway long enough at the time of this writing to provide substantial ongoing cost information. (Our cost analysis for the Ivory Coast is based on information from planning documents prepared prior to project initiation; our analysis for Indonesia is based on a planning document for a project not undertaken.) In all cases the analysis is based on data subject to substantial error, and our divisions of costs into various categories is sometimes based on incomplete information and hence may be somewhat arbitrary. The reader should view our conclusions as approximations.

To put the costs into a form that permits the projects to be compared with one another we have done four things. First we con-

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[12] Cost information on other uses for the media, including several teacher training and adult education projects, may be found in the Schramm, et al. [1967] case studies. Wagner [1972] and Lumsden [1972, unpublished] provide cost information on the Open University in the U.K.; Dordick [unpublished] provides cost information on the Bavarian Telekolleg in Germany; Baldwin, Davis, and Maxwell [1972] provide detailed cost information on a program of Colorado State University to distribute graduate engineering instruction by videotape; and Krival [1970] provides cost information on use of radio and correspondence for teacher training in Kenya. Dodds [1972] reviews some of these and additional uses of media for non-formal education, and provides cost information in some cases. The cost data reported in these papers on non-formal education are amenable to the same methods of analysis used in this paper. For a discussion of the costs, and cost projections, of the school television program in Niger see Lefranc [1967]; we have not included it because of the small number of students involved.

verted all costs into 1972 dollars by converting from the foreign currency to U.S. currency at the exchange rate prevailing at the time the information was gathered, then used the U.S. GNP deflator to convert to 1972 dollars. (Due to differing relative prices in different countries and exchange rate rigidities, there may be distortions introduced by this procedure — see Vaizey, et al [1972, Chapters 15 and 16]. We believe that since these cost comparisons are among developing countries, the resulting distortions will be relatively small.) Second, we use the same interest rates (social rate of discount) to evaluate each project. To allow examination of the sensitivity of the conclusions to the rates chosen (see footnote 7), we use three values for the interest rate — 0, 7.5%, and 15% per year. Third, we have attempted to include and exclude the same items in each cost analysis. We include program production costs, central administration costs, transmission costs, and reception costs. We exclude the costs of teacher retraining and printed material. Fourth, we have assumed common capital lifetimes for all projects — 25 years for buildings and start-up costs, 10 years for transmission and studio equipment, and 5 years for receivers.

In subsection III.A we utilize the methodology of subsection II.B to compute annualized cost functions for the 8 projects we include in our analysis; the results are presented in two tables -- one for television and one for radio. In subsection III.B we utilize the methodology of subsection II.C to compute the average cost from i to j for the El Salvador and Ivory Coast television projects.

A. Annualized Cost Data for 8 Projects

In this subsection we derive annualized cost functions for the 5 television and 3 radio projects. In each case we have approximated the total cost function by the linear form of equation 1 in Section II; that is, we assume there to be a fixed cost, F, and a variable cost, V, such that total cost, $TC(N)$, is given by $TC(N) =$

$F + VN$, where N is the number of students using the system. For each project we have taken as given the number of hours per year that the student uses the system and the geographical area served.[13] To obtain the values for F and V we allocated each cost into one of 4 categories: fixed, capital; fixed, recurrent; variable, capital; and variable, recurrent. By variable we mean, of course, for these purposes, variable with respect to the number of students. Capital costs were then annualized using equation (2) of section II, and the cost function was constructed by letting F equal the sum of all fixed cost components and V equal the sum of all variable cost components.

Colombia. In 1964 Colombia began a program of providing instructional television that now reaches approximately 500,000 students in almost 1200 schools. Initially designed to enrich the learning environment of students and provide models of exemplary teaching to the teachers, beginning in 1973 the program will move more into mainline instruction.[14] The basic source of the cost data used in our analysis is from the IIEP case study prepared by Lyle [1967] in late 1965. At that time about 275,000 students were receiving television lessons; the average student viewed 50.25 hours during the course of the academic year.

The IIEP case provides data on the replacement value of the capital in use for instructional television in 1965, under the assumption that its fraction of the total capital value of the television broadcasting system was proportional to the number of broadcast hours it used. We use these data, though the depreciation

[13] Layard [1973] provides a valuable discussion of the cost-effectiveness lessons that can be drawn from explicit consideration of a 2 variable cost function where, in addition to N , he explicitly considers hours of programming required.

[14] The preceding information was obtained during a visit by one of the authors to INRAVISION, the system's production headquarters, in Bogota, August 1972.

and interest charges used in the IIEP case cannot be derived from them by the procedures said to be used. Recurrent costs of programming, transmission, and reception are also given, and we use these as stated.

The following equations give our assessment of the cost function, as well as average cost and cost per student hour for N equal to 275,000 and h , the number of hours a typical student views per year, equal to 50.25. The ratio AC/V of the average cost to the variable cost (V also is the marginal cost of adding a student for a year) is a measure of the extent to which economies of scale have been realized; if AC is high relative to marginal cost, expanding the system could substantially reduce average costs. Our cost equations are:

	total cost equation	AC	AC/V	student-hr. cost
r = 0	TC(N) = 535,000 + .793N	2.74	3.19	.054
r = 7.5%	TC(N) = 624,000 + .859N	3.13	3.95	.062
r = 15%	TC(N) = 728,000 + .932N	3.58	3.84	.071 .

All values are in 1972 U.S. dollars, and the reader is reminded that the coefficients for fixed and variable cost in the total cost equation include depreciation and interest charges through use of the annualization formula of equation 2. The 7.1¢ cost per student hour that results from a 15% annual social discount rate is very close to the 7.0¢ that is obtained in the IIEP case study, if their figure is adjusted for subsequent inflation. Though close, the figures follow from markedly different ways of treating capital costs. It is worth noting that one obtains a 31% higher average cost if r = 15% rather than 0.

<u>American Samoa</u>. The six channel instructional television system in American Samoa must stand as one of the most ambitious and widely watched instructional technology projects yet undertaken. Television has taught the core of the curriculum to most Samoan students since 1964; a history of its introduction and early evaluation may be found in Schramm [1967].

Our cost estimates are based on information concerning system cost and utilization from the 1972-73 school year[15] that allocates costs among three uses -- school TV, adult TV, and early childhood education TV. We examine only the school TV component. The costs of school TV came divided into recurrent production costs, recurrent distribution costs, and capital replacement costs. From the capital replacement costs we derived an estimate of the of total capital value, and by using the same ratios for fixed and variable costs that are implicit in the Schramm [1967, p. 38] case study for IIEP, we are able to separate approximately fixed and variable costs.

To obtain cost averages we need to have values for N and h. During the 1972-73 school year N equals 8100. Estimating h is subject to substantially more uncertainty. Early in the project it was hoped that h would reach 365 hours per student per year; since then per student usage has decreased and in 1972-73 about 1575 new programs will be produced for all 11 grades. A recent estimate is that about 3150 previously taped programs will also be broadcast; these programs range in length from 15 to 30 minutes. Utilization of some of these programs is voluntary and thus we assume, with Professor Schramm, that the programs are, on the average, used only 90% of the time. Assuming an average of 22.5 minutes per program and that the number of viewing hours in a grade is not highly correlated with the number of students in the grade, we find $h = 145$ hours per year. We use this value in computing the final column below, but the reader should bear its uncertain origin in mind. The cost values are:

	total cost equation	AC	AC/V	student-hr. cost
$r = 0$	$TC(N) = 1{,}189{,}000 + 2.63N$	149.42	56.8	1.03
$r = 7.5\%$	$TC(N) = 1{,}268{,}000 + 3.06N$	159.60	52.2	1.10
$r = 15\%$	$TC(N) = 1{,}360{,}000 + 3.52N$	171.42	48.7	1.18 .

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[15] Professor Wilbur Schramm provided us this information, which he gathered while preparing a forthcoming new case study on the Samoa project.

The high cost per student hour is due to the geographical inability of the system to realize economies of scale; the extent to which economies of scale are unrealized is vividly illustrated in the AC/V column. The difference between a 0 and 15% interest rate results in an increase of 15% in average costs; this is smaller than for Colombia because of the high level of recurrent costs in Samoa.

Mexico. The Mexican Telesecundaria system was initiated in 1968 as a means of bringing secondary schooling to rural and semi-rural communities through the use of television. The cost data used here were gathered by Klees and are presented in Mayo, McAnany, and Klees [1973]. The assumptions made in our analysis are identical to those in the original source, with the exception of the value used for the social discount rate (Klees used 10%). In 1972 the system was broadcasting about 360 hours a year to each of its 29,000 students. These figures are used in the cost equation below:

	total cost equation	AC	AC/V	student-hr. cost
r = 0	TC(N) = 562,000 + 3.65N	23.03	6.31	.064
r = 7.5%	TC(N) = 598,000 + 4.23N	24.85	5.87	.069
r = 15%	TC(N) = 643,000 + 4.85N	27.02	5.57	.075 .

The original source presents more detailed information on these costs as well as on classroom teacher costs, facility costs, and sources of finance; it also compares Telesecundaria costs and performance with that of the traditional system.

El Salvador. The El Salvador instructional television system began broadcasting in 1969 to secondary school students; recently there have been plans to extend the system to cover elementary school, and broadcasts to the fourth grade started on a pilot basis this year. Our analysis will consider the costs of the system with and without elementary school coverage. In addition, because a substantial amount of the funding for the project came from foreign grants and loans, we will examine costs both from the point of view of total project costs (including the grant and loan money) and from the viewpoint of costs to the Government of El Salvador (GOES) only. The GOES costs are, of course, substantially less than total project costs.

Consequently we examine four alternatives: (a) total costs for secondary school only, (b) GOES costs for secondary school only, (c) total costs for elementary and secondary school coverage, and (d) GOES costs for elementary and secondary school coverage. Cost timetables for each of these four alternatives are given in tables III.3 and III.4 in subsection III.B. Since the present system covers only the secondary level, the cost estimates for alternatives c and d rely heavily on projections. The cost data is based on Speagle [1972] except where footnotes to these tables indicate otherwise. To proceed from the cost timetables to annualized cost figures additional assumptions had to be made and these are explained for each alternative.

a. In estimating the total system costs alternative for secondary school coverage start-up costs were treated as an initial capital investment in the system and were annualized over the assumed 25 year lifetime of the system. The 1972 student enrollment estimate of 48,000 was used along with the assumption of an average of 170 hours of programming per grade per year.

The total cost equation for the secondary system is as follows:

	total cost equation	AC	AC/V	student-hr. cost
$r = 0$	$TC(N) = 904{,}000 + .89N$	19.72	22.16	.116
$r = 7.5\%$	$TC(N) = 1{,}116{,}000 + 1.10N$	24.35	22.14	.143
$r = 15\%$	$TC(N) = 1{,}346{,}000 + 1.33N$	29.37	22.08	.173 .

b. In looking at the costs to El Salvador of secondary school coverage it is necessary to reduce the total expenditures given above by an annualized equivalent of the grants and loans.[16] To find this equivalent the present value of the 30 year loan repayment series was calculated and this was subtracted from the total amount of the foreign grants and loans (the total amount was assumed to occur in the year 1970). The resulting figure was annualized over the 25 year assumed lifetime of the project and subtracted from the fixed costs. The unusual behavior of the fixed costs — they <u>decrease</u> as the discount rate increases -- is explained by observing that the loans and grants are worth more in annualized equivalents as r increases. The GOES cost equation for secondary only is as follows:

	total cost equation	AC	AC/V	student-hr. cost
r = 0	TC(N) = 806,000 + .89N	17.68	19.87	.104
r = 7.5%	TC(N) = 799,000 + 1.10N	17.75	16.13	.104
r = 15%	TC(N) = 771,000 + 1.33N	17.39	13.08	.102 .

c. To estimate the total system costs when elementary school coverage was included several assumptions additional to those needed for alternative (a) were made. First, production and transmission operations were costed at the level they will assume after all six elementary grades are brought into the system -- $1,290,000 and $15,000 per year respectively. Second it was assumed that 10% of enrollment in the future would be secondary school students and 90% elementary. Therefore, an average class size of 54 (assumed to be 45 for secondary and 55 for elementary) was used to allocate television receiver and elementary school classroom remodeling. The student enrollment figure used below is 990,000 which is that projected for 1980, the first year of full nine grade coverage. The number of

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[16] Because of the grants and soft loans total costs exceed GOES costs. Table III.3 shows the extent of this in the rows labeled 'total costs,' 'foreign aid and debt repayment,' and 'total cost to GOES'. In the first years of the project, 'total cost to GOES' is obtained by <u>subtracting</u> foreign aid (in parenthesis) from 'total cost'. In later years 'total cost to GOES' is obtained by <u>adding</u> debt repayment to 'total cost'.

programs per grade per year is again assumed to be 170. The total cost equation for the elementary plus secondary system is as follows:

	total cost equation	AC	AC/V	student-hr. cost
r = 0	TC(N) = 1.698,000 + .75N	2.47	3.29	.015
r = 7.5%	TC(N) = 1,920,000 + .94N	2.88	3.06	.017
r = 15%	TC(N) = 2,162,000 + 1.16N	3.34	2.88	.020 .

d. Our estimate of the cost to El Salvador for elementary and secondary school coverage is based on combining the assumptions of alternative (b) with those of alternative (c). The cost equation is:

	total cost equation	AC	AC/V	student-hr. cost
r = 0	TC(N) = 1,600,000 + .75N	2.37	3.15	.014
r = 7.5%	TC(N) = 1,603,000 + .94N	2.56	2.72	.015
r = 15%	TC(N) = 1,587,000 + 1.16N	2.76	2.38	.016 .

Notice, once again, the unusual behavior of the fixed costs.

Our cost estimates for El Salvador are generally higher than the estimates made by Speagle, even when we use a social discount rate of zero as Speagle did. Primarily this is because our analysis of average costs included start-up, video tape, transmission operations, and classroom remodeling cost components. When a reasonable rate of interest is used the difference between Speagles' estimates and ours becomes more pronounced. In 1972 Speagle estimated the average total cost per student to be $16.00 (using N = 40,000). Our comparable estimate for the actual value of N in 1972, 48,000, was $19.72 for r = 0 and $24.35 for r = 7.5%. If we had used his value of N our average costs would have been still higher -- $23.49 for r = 0 , and $29.00 for r = 7.5%.

Ivory Coast. Although the ETV system in the Ivory Coast began broadcasting to first grade elementary school classes in 1971, no source of actual cost data is publicly available. Consequently, the source of cost data for our analysis is an IIEP Ivory Coast ETV planning study done in 1970. A cost timetable for the project was developed through 1988 and is presented in Table III.5 in subsection III.B, along with the assumptions additional to those in the IIEP study that were needed to create the timetable. The IIEP costs are themselves modifications of an Ivory Coast planning study (Ministere de l'Education Nationale [1968; vol. I, ch. VII; vol. II, ch. VII]).[17]

To proceed from the cost timetable to an annualized version of costs several more assumptions needed to be made. Production operations were assumed to have a normal annual cost of $860,000 if the system were broadcasting to all six grades. Costs above this incurred in production operations during the first 10 years of the project were treated as a start-up investment and annualized over the lifetime of the project (assumed to be 25 years). Recurrent transmission and maintenance costs were estimated at the full six grades operation level of $340,000 and $70,000 respectively. The recurrent costs of reception were estimated from the following linear expression: $432,000 + $1.73 N .

Since annualized costs are examined in terms of their magnitude under conditions of full six grade operation the student enrollment figure used in the following calculations is the 745,000 projected for 1980, the first year of operation in six grades. Each student is assumed to receive an average of 180 hours of ETV programming each year.

The cost equation of the system is as follows:

	total cost equation	AC	AC/V	student-hr. cost
r = 0	TC(N) = 2,163,000 + 3.55N	6.45	1.82	.036
r = 7.5%	TC(N) = 2,454,000 + 3.98N	7.27	1.83	.040
r = 15%	TC(N) = 2,741,000 + 4.44N	8.12	1.83	.045 .

[17] There is reason to believe that these planned costs are substantial underestimates of what actual costs have been

Our cost estimates above are greater than those of the IIEP study. This is due to completely different methods of analysis. The IIEP analysis of unit costs did not include capital costs nor did it annualize costs; it simply divided total operating costs in a given year by the number of students being served in that year.

Thailand. Substantially less experience based information exists on the cost of instructional radio than for instructional television. Perhaps the best available information is from the Thai radio education project that began in May, 1958. This project broadcasts relatively small amounts of instruction in music, social studies, and English to about 800,000 elementary and beginning secondary level students; in addition, a 30 minute children's lunch hour program provides education and entertainment during the noon break. Schramm [1967] describes the Thai project and provides the basic cost data that we use for our analysis.

We divide the cost information that Schramm provides into fixed and variable and capital and recurrent in ways that seem natural, then apply our annualization methods to obtain total cost functions. These follow:

	total cost equation	AC	AC/V	student-hr. cost
r = 0	TC(N) = 89,340 + .182N	.294	1.61	.012
r = 7.5%	TC(N) = 100,400 + .221N	.347	1.57	.014
r = 15%	TC(N) = 114,700 + .263N	.406	1.55	.016 .

The per student hour costs obtained are very close to those of Schramm, but this results from two counterbalancing factors. Our estimated average cost of 35¢ (at r = 7.5%) is over double Schramm's estimate of 15¢. This is due in part to a higher interest charge than he uses, but mostly to our using a 5 instead of 10 year lifetime for the expensive (132 1972 dollars each) radio receivers. We assumed that with a 5 year lifetime replacement would take the place of maintenance. This assumption of a 5 year lifetime is perhaps over-conservative since part of the reason for high receiver cost was that rugged, long life receivers were purchased.

Counterbalancing our higher estimate of per student annual costs is our somewhat higher estimate of student usage. To obtain a per student hour cost of 1¢ (1.32 1972 ¢), Schramm assumes that h has the very low value of 15 hours per student per year; we use 25. Music is broadcast for 1/6 hour per week per grade level offered, English 1/3, and social studies 1/2; the lunch hour program is broadcast 2 1/2 hours per week. The school year lasts 30 weeks so that, if a student took the median lengthed English course and listened to the noon hour program once a week, he would listen for 25 hours per year; this is the basis of our computation of costs per student hour. What is important is not the actual number, but the observation that costs per student hour respond sensitively indeed to the level of per student utilization.

It is valuable to note that radio can reach student-hour costs of 1.5¢ even with highly costly receivers and a low utilization rate.

Mexico. Mexico's Radioprimaria is an experimental program that began in 1969 with the objective of using radio to provide fourth, fifth, and sixth grade education to those rural and semi-rural communities that had conventional elementary schools with only the first three grades. Fourth, fifth, and sixth grade students are in one classroom with one teacher and about 80% of the broadcasts are aimed at this combined audience; the remaining 20% are divided among the three grades.

Spain [1973] describes Radioprimaria and reports cost data that were gathered by Klees. The assumptions used to obtain the results below are identical to those made in Spain. The number of students in the system in 1972 was 2800 and this value is used for N . There are approximately 270 total hours of programming broadcast to the three grades each year. Using the information above (that 80% of the broadcasts are aimed at the joint audience) we used a figure of $h = 233$ as the number of hours received per student per year.

The cost equation is:

	total cost equation	AC	AC/V	student-hr. cost
r = 0	TC(N) = 36,400 + .09N	13.09	145.44	.056
r = 7.5%	TC(N) = 37,700 + .11N	13.57	123.40	.058
r = 15%	TC(N) = 39,100 + .13N	14.09	108.42	.061

The reason for the relatively high per student-hour cost lies in the experimental nature of the project; the values of AC/V are over twice those of even the Samoan television project. If student usage were to go up to the level of the Mexican Telesecundaria project (N = 29,000), per student-hour costs would drop to .6¢, assuming r = 7.5%.

Indonesia. The paucity of information on the costs of ongoing instructional radio projects has led us to include cost estimates from a planning study on Indonesia conducted for UNESCO by one of the present authors -- see Jamison [1971]. One of the systems analyzed, 'Radio 5,' would provide 20 to 30 minutes of instruction daily in each of two subject matters; this would yield a value of h of 100 hours per year or a little more. The Indonesia analysis assumed high programming costs ($1000 per hour), worst case transmission costs, and moderate reception costs. When the interest and depreciation charges are put into the framework of the present analysis, and an 8 year lifetime is assumed for programs, the cost equations become:

	total cost equation	AC	AC/V	student-hr. cost
r = 0	TC(N) = 75,000 + .28N	.34	1.22	.0034
r = 7.5%	TC(N) = 102,400 + .32N	.41	1.27	.0041
r = 15%	TC(N) = 133,700 + .37N	.48	1.30	.0048

The average cost figures above are based on the assumption that most economies of scale have been realized (AC/V is low) with a student user population of 1.2 million. This is approximately 10% of the present elementary school population of Indonesia; the cost estimates allow for a dispersed transmission system so that this 10% of students could be spread through the archipelago.

The per student hour cost is between 1/3¢ and 1/2¢ depending on the value of r ; this strong percentage cost difference across a range of reasonable values for r provides good reason for making explicit the sensitivity of one's results to the social rate of discount.

<u>Summary of Costs of the 8 Projects</u>. Tables III.1 and III.2 summarize the annualized cost information for the 5 instructional television and 3 instructional radio projects. The information is

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Insert Tables III.1 and III.2 about here

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provided for the 7.5% value for the social rate of discount.

B. The Time Structure of Average Costs for 2 Projects

For 2 of the projects discussed in the preceding subsection we have data on the time structure of expenditures as well as student usage. Speagle [1972], in a valuable study, provides for El Salvador what is perhaps the most detailed accounting yet available of the costs of an educational technology project. The IIEP provides time structured costs in somewhat less detail in a planning study for the Ivory Coast. Their estimates are prior to initiation of the project, now in its second year of operation, but provide a good feel for the type of information a decisionmaker could have available to him before committing himself. With these time structured cost and utilization figures we can use the methods of subsection II.C to examine how average costs appear from different points into a project when one views to different time horizons.

Table III.1:

COST SUMMARY OF 5 INSTRUCTIONAL TELEVISION PROJECTS[a,b]

Project	Year of Information Source	N	h	F	V	AC	AC/V	Student-Hr. Cost
Colombia	1965	275,000	50.25	624,000	.859	3.13	3.95	.062
American Samoa	1972	8,100	145	1,268,000	3.06	159.60	52.2	1.10
Mexico	1972	29,000	360	598,000	4.23	24.85	5.87	.069
El Salvador	1972							
(a) Total Costs, Sec. Only		48,000	170	1,116,000	1.10	24.35	22.14	.143
(b) GOES Costs, Sec. Only		48,000	170	779,000	1.10	17.75	16.13	.104
(c) Total Costs, Elem. & Sec.		990,000[c]	170	1,920,000	.94	2.88	3.06	.017
(d) GOES Costs, Elem. & Sec.		990,000[c]	170	1,603,000	.94	2.56	2.72	.015
Ivory Coast	1970	745,000[c]	180	2,454,000	3.98	7.27	1.83	.040

[a]Values in this table were computed with a social discount rate of 7.5%; all values are in 1972 U.S. dollars.

[b]The symbols are defined as follows: N = number of students using project (in the given year, unless otherwise noted); h = number of hours per year a typical student views programs; F = annualized fixed costs; V = annualized variable costs; AC = average cost per student for the given value of N ; and the student-hr. cost is the cost per student-hour of viewing for the given value of N .

[c]These values of N are planned student usage for 1980.

Table III.2:

COST SUMMARY OF 3 INSTRUCTIONAL RADIO PROJECTS[a,b]

Project	Year of Information Source	N	h	F	V	AC	AC/V	Student-Hr. Cost
Thailand	1967	800,000	25	100,400	.221	.347	1.57	.014
Mexico	1973	2,800	233	37,700	.11	13.57	123.40	.058
Indonesia[c]	1971	1,200,000	100	102,400	.32	.41	1.27	.0041

[a]Values in this table were computed with a social discount rate of 7.5%; all values are in 1972 U.S. dollars.

[b]The symbols are defined as follows: N = number of students using project (in the given year, unless otherwise noted); h = number of hours per year a typical student views programs; F = annualized fixed costs; V = annualized variable costs; AC = average cost per student for the given value of N ; and the student-hr. cost is the cost per student-hour of viewing for the given value of N .

[c]The Indonesia figures are based on a planning study, not project experience.

<u>El Salvador</u>. We provide 4 separate analyses of the El Salvador data. The first two are based on the assumption that television is used solely for secondary education, as was originally intended. The second two are based on the assumption that the television system is expanded to include elementary level education; our present information is that, beginning this year, the system will be so expanded. For both these use patterns for the system we analyze total costs and costs to the Government of El Salvador (GOES); GOES costs are, of course, less than total costs since much of the early financing of the project was through external grants and soft loans.

Tables III.3 and III.4 show the time pattern of costs and

Insert Tables III.3 and III.4 about here

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student usage for the system; III.3 contains the information for secondary only, and III.4 contains the information for elementary and secondary. These tables are of the same format as table II.2, only richer in detail. One row in the table gives the level of grants and loans that must be subtracted from total cost to give GOES costs. Loan repayment commences after 10 years and extends for 30 years thereafter; repayments are also shown in the tables. In computing repayments in 1972 dollars we have taken into account the (variable) interest rate on the loan and assumed an average annual rate of inflation of 4% for the dollar over the period of the loan. The sources and justification of the tables appear in footnotes to them.

Rather than include the extensive tables containing the AC_{ij}s here in the text, they are attached as Appendix D. Appendix D has 12 tables; for each of the 4 cases we examine, we used discount rates of 0, 7.5%, and 15% per annum. This indicates the sensitivity of the results to the interest rate chosen. Figures III.1 to III.3 illustrate

Table III. 3:

COSTS OF ITV IN EL SALVADOR -- SECONDARY SCHOOL ONLY[a]
(thousands of 1972 U.S. Dollars)

	Year																						
	1966	1967	1968	1969	1970	1971	1972	1973	1974	1975	1976	1977	1978	1979	1980	1981	1982	1983	1984	1985	1986	1987	1988
PRODUCTION																							
Facility					234	108	36	36							36	36							
Equipment			50	270	40	966							50	270	40	966							
Operations				300	370	410	490	490	490	490	540	540	540	540	540	540	540	540	540	540	540	540	540
Start-up	50	50	380	360	260	210	200	200	100	50													
Video-Tape				51	51	51			51	51	51			51	51	51			51	51	51		
TRANSMISSION																							
Facility					26	12	4	4							4	4							
Equipment						644										644							
Operations				20	20	40	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10
RECEPTION																							
Classroom Remodeling			1090																				
Equipment			50		120	120	120	53	62	80	13	13	13	18	13	18	18	18	13	18	18	22	18
Replacement								50		120	120	120	103	62	200	133	133	116	80	213	151	151	134
TOTAL COSTS	50	50	1570	1001	1121	2561	860	843	713	801	734	638	716	951	934	2402	701	684	694	832	770	733	702
FOREIGN AID & DEBT REPAYMENT			(190)	(680)	(300)	(1980)	(320)	(320)							45	45	45	45	45	45	45	45	45
TOTAL COST TO GOES	50	50	1380	321	821	581	540	523	713	801	734	638	716	951	979	2447	746	729	739	877	815	768	747
NUMBER OF STUDENTS (in thousands)				2	14	32	48	60	72	86	104	107	110	113	117	120	124	128	131	135	139	144	148

[a]Footnote starts on next page.

Footnote to Table III.3

[a]Cost data are based mainly on Speagle [1972] for 1966 to 1973 and partly on conversations with the Stanford University Institute for Communications Research group responsible for an ongoing study of ITV in El Salvador. The rationale for each projection or alteration from Speagle's estimate is as follows:

Production facility. Ninety per cent of the costs of the Santa Tecla facility were allocated to production and 10% to transmission, with the life of the air conditioning assumed to be 10 years and the facility life to be 25 years.

Production equipment. This assumes a 10 year life, with the cost of the Santa Tecla equipment allocated 60% to production and 40% to transmission.

Production operations and start-up. These are the same as Speagle until 1974 when start-up costs are assumed to decrease over two years to a $50,000 level. After 1975 they remain at this level and are included in the cost of operations which are based on Speagle's projection.

Video tape. It is not clear whether these costs are included in Table 2.1 of Speagle. They are added here, purchased as needed, under the assumption of a 5 year tape life, 300 hours of programming a year, and a cost of an hour length video tape of $170.

Transmission facility. This is explained under production facility.

Transmission equipment. This is explained under production equipment.

Transmission operations. This represents the rental charge through 1971 for the use of commercial broadcast time. Beginning in 1972 operations are expected to cost 25% of the 1971 rental charge.

Classroom remodeling. This is the same as in Speagle, with an assumed 25 year lifetime.

Reception equipment. Beginning in 1973 this is based on the number of students added to the system, an average class size of 45, and a cost per receiver of $200.

Reception equipment replacement. This is based on the equipment cost stream in the table and an assumption of a 5 year life.

Foreign aid and debt repayment. Through 1973 this represents the actual size of foreign grants and loans. The loan portion of this aid is paid off with a 10 year grace period during which interest accumulates at 2% and a 30 year repayment period during which interest accumulates at 2.5%. With our assumption of a 4% annual rate of inflation these effective interest rates become -2% and -1.5% respectively. If there were no inflation present, value of the repayment amount would be almost three times as large. The repayment is scheduled as if the 40 year period for the total loan began in 1970.

Number of students. This is assumed to grow rapidly from 1972 to 1976 (about 20% per year) after which a 3% growth rate is accounted for mainly by population growth.

Footnote to Table III.3 (cont.)

The cost data do not include teacher training (not considered by Speagle as part of ITV costs), the distribution and printing of teachers guides and student workbooks, nor maintenance and power costs for reception equipment (Speagle says this latter is extremely small).

Table III. 4:

COSTS OF ITV IN EL SALVADOR -- ELEMENTARY AND SECONDARY SCHOOL COVERAGE[a]
(thousands of 1972 U.S. Dollars)

	Year																						
	1966	1967	1968	1969	1970	1971	1972	1973	1974	1975	1976	1977	1978	1979	1980	1981	1982	1983	1984	1985	1986	1987	1988
PRODUCTION																							
Facility					234	108	36	36							36	36							
Equipment			50	270	40	966							50	270	40	966							
Operations				300	320	410	490	615	740	865	915	1040	1165	1290	1290	1290	1290	1290	1290	1290	1290	1290	1290
Start-up	50	50	380	360	260	210	200	200	100	50													
Video-Tape				51	51	51		17	68	68	51	17	34	85	68	51	17	34	85	68	51	17	34
TRANSMISSION																							
Facility					26	12	4	4							4	4							
Equipment					644							50				644						50	
Operations				20	20	40	10	10	10	10	10	15	15	15	15	15	15	15	15	15	15	15	15
RECEPTION																							
Classroom Remodeling			1090					1	33	29	28	5	95	63	60	16	17	18	18	19	20	21	23
Equipment			50		120	120	120	60	393	371	297	64	958	651	609	178	185	196	195	211	222	233	243
Replacement								50		120	120	120	110	513	491	417	184	1068	1164	1100	595	369	1264
TOTAL COSTS	50	50	1550	1001	1101	2591	860	993	1344	1513	1421	1311	2431	2887	2613	3617	1708	2625	2767	2703	2193	1995	2873
FOREIGN AID & DEBT REPAYMENT			(190)	(680)	(300)	(1980)	(320)	(320)							45	45	45	45	45	45	45	45	45
TOTAL COST TO GOES	50	50	1380	321	801	611	540	673	1344	1513	1421	1311	2431	2887	2658	3662	1753	2683	2812	2748	2238	2040	2918
NUMBER OF STUDENTS (in thousands)				2	14	32	48	62	165	259	355	372	635	822	990	1037	1087	1139	1192	1249	1309	1372	1438

[a]Footnote starts on next page.

Footnote to Table III.4

[a]This table analyzes cost implications of the assumption that El Salvador expands ITV coverage to include elementary school. Implementation is assumed to begin with 2000 fourth grade students in 1973, to cover all of fourth grade as well as the experimental group now in the fifth grade in 1974, and in 1975 to cover all of fourth and fifth as well as the experimental group now in the sixth grade. To this point one grade of programming has been added each year. In 1976 no new programming is added, however; revision proceeds on the basis outlined in Speagle [1972] and the system is expanded to cover the entire sixth grade. Beginning in 1977 the process is repeated with the first to third grades. In 1980 all of elementary and secondary school will be covered. This implementation scheme appears to be in general accord with present tentative plans of the Ministry of Education in El Salvador.

Cost data are based mainly on Speagle [1972] and partly on conversations with members of the Stanford University Institute for Communications Research group responsible for an on-going study of ITV in El Salvador. The rationale for each projection or alteration from Speagle's estimate is as follows:

Production facility. Ninety per cent of the costs of the Santa Tecla facility were allocated to production and 10% to transmission, with the life of the air conditioning assumed to be 10 years and the facility life to be 25 years.

Production equipment. This assumes a 10 year life, with the cost of the Santa Tecla equipment allocated 60% to production and 40% to transmission.

Production operations and start-up. Start-up expenses are the same as in Speagle until 1974 when they are assumed to decrease over two years to a level of $50,000. After 1975 they remain at this level and are included in operations. Operations estimates are the same as Speagle up until 1972 after which they increase to about two and a half times that level over the period of implementation of elementary school programming (1973 to 1979).

Video tape. It is not clear whether these historical costs are included in Table 2.1 of Speagle. They are added here, purchased as needed, under the assumption of a 5 year tape life, an average of 300 hours of programming a year for secondary school starting in 1969, and a cost of an hour length video tape of $170. For elementary schooling, programming begins in 1973 at the rate of 100 hours per grade per year in accordance with the implementation scheme. Video-tapes are purchased as needed in accordance with this scheme.

Transmission facility. This is explained under production facility.

Transmission equipment. This is explained under production equipment, except for the $50,000 expense in 1977 which is the cost of adding another channel which would be needed to provide coverage to grades 1 through 3.

Transmission operations. This represents the rental charge through 1971 for the use of commercial broadcast time. Beginning in 1972, with the opening of the Santa Tecla facility, operations are expected to cost 25% of the 1971 rental charge. In 1977 these costs increase by 50% with the addition of another channel.

Footnote to Table III.4 (cont.)

Classroom remodeling. The expense for secondary schools is as in Speagle. Subsequent charges are for elementary school classrooms, many of which have been recently built. It is estimated that any classroom improvements (i.e., a stand and locked cabinet) can be obtained for an average of $20 per classroom. Implementation proceeds as elementary classrooms are added to the system with an assumed average class size of 55.

Reception equipment. Beginning in 1973 this is based on the amount of students added to the system, an average class size of 45 for secondary school and 55 for elementary school, and a cost per receiver of $200.

Reception equipment replacement. This is based on the equipment cost stream above and an assumption of a 5 year life.

Foreign aid and debt repayment. Through 1973 this represents the actual size of foreign grants and loans. The loan portion of this aid is paid off with a 10 year grace period during which interest accumulates at 2% and a 30 year repayment period during which interest accumulates at 2.5%. With an assumption of a 4% annual rate of inflation these effective interest rates become -2% and -1.5% respectively. If there were no inflation the repayment amount would be almost three times as large. The repayment is scheduled as if the 40 year period for the total loan began in 1970.

Number of students. For secondary school, this is assumed to grow rapidly from 1972 to 1976 (about 20% per year) after which a 3% growth rate is accounted for mainly by population growth. For elementary school, total enrollment was projected (as in Speagle) at about 5% a year. During the 1973-1979 implementation phase grade by grade enrollment figures were used in accordance with the elementary school implementation design.

The cost data does not include teacher training (not considered by Speagle as part of ITV costs), the distribution and printing of teachers guides and student workbooks, nor maintenance and power costs for reception equipment (Speagle says this latter is extremely small).

Insert Figures III.1 - III.3 about here

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this graphically; in them AC_{1j} , AC_{5j} , and AC_{8j} are shown for various values of j for the total cost of the secondary only system in El Salvador. It is clear from that figure that assumptions concerning interest rates critically affect average cost estimates, particularly as viewed from prior to project initiation; the low curve corresponds to $r = 0$, the middle one to $r = 7.5\%$, and the high one to $r = 15\%$.

Ivory Coast. For the Ivory Coast we have analyzed planning data for the elementary school television system that is now in its second year of operation. Table III.5 shows our analysis of the time streams

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Insert Table III.5 about here

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of costs and student usage; the derivation of that table appears in a footnote to it. We hope in the near future to be able to compare actual costs (for the first several years) to the planned costs, and to separate costs incurred by the Government of the Ivory Coast from the total costs displayed in Table III.5. See footnote 17.

Appendix E contains tables showing AC_{ij} for the Ivory Coast for three interest rates; Figures III.4 to III.6 show AC_{1j} ,

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Insert Figures III.4 - III.6 about here

AC_{5j} , and AC_{8j} as a function of j for the 0, 7.5%, and 15% interest rates. Notice that the scale of the vertical axis is different for each of these 3 figures.

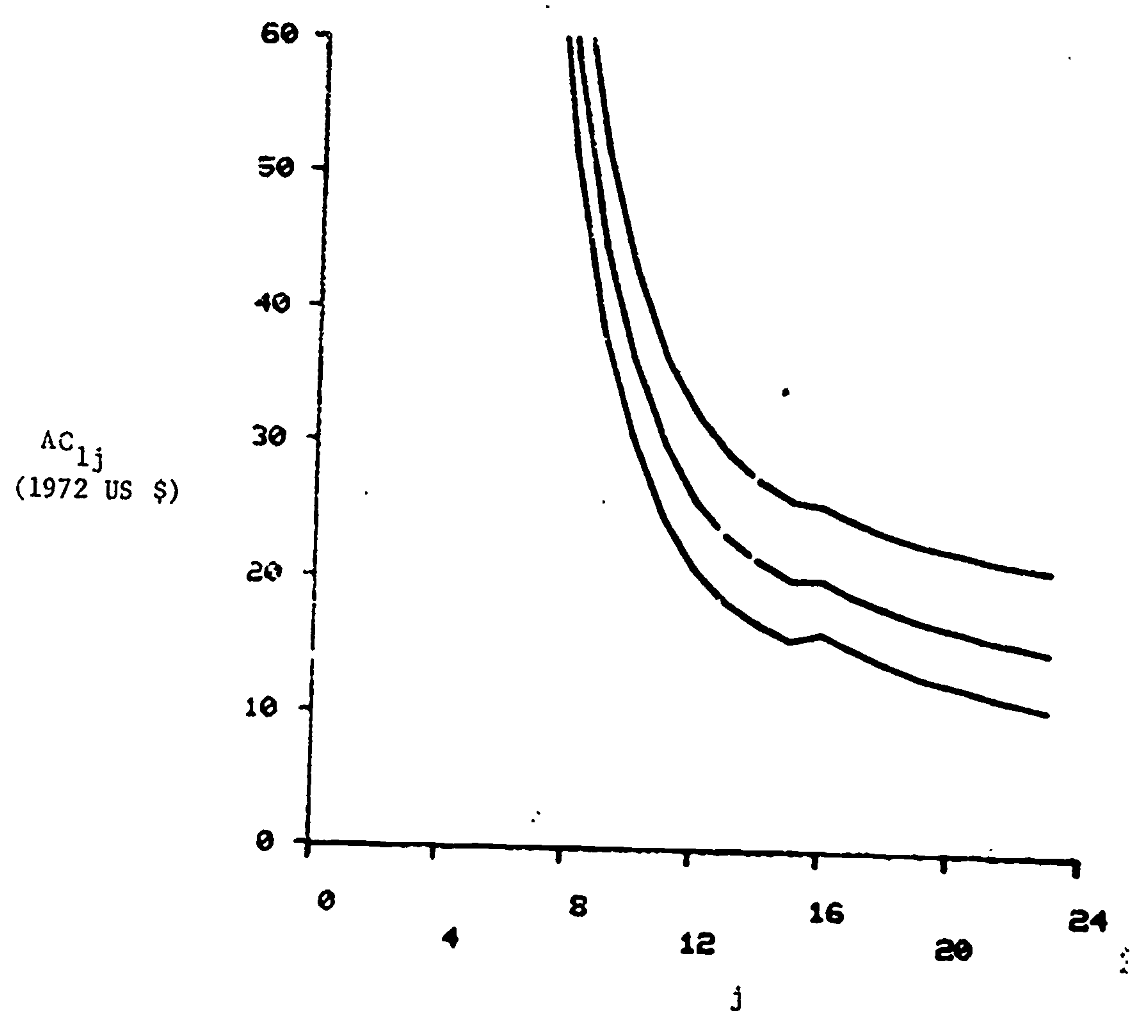

Fig. III.1: AC_{1j} for the Total Cost of Secondary in El Salvador (The top curve assumes a social discount rate of 15%, the middle one 7.5%, and the bottom one 0.)

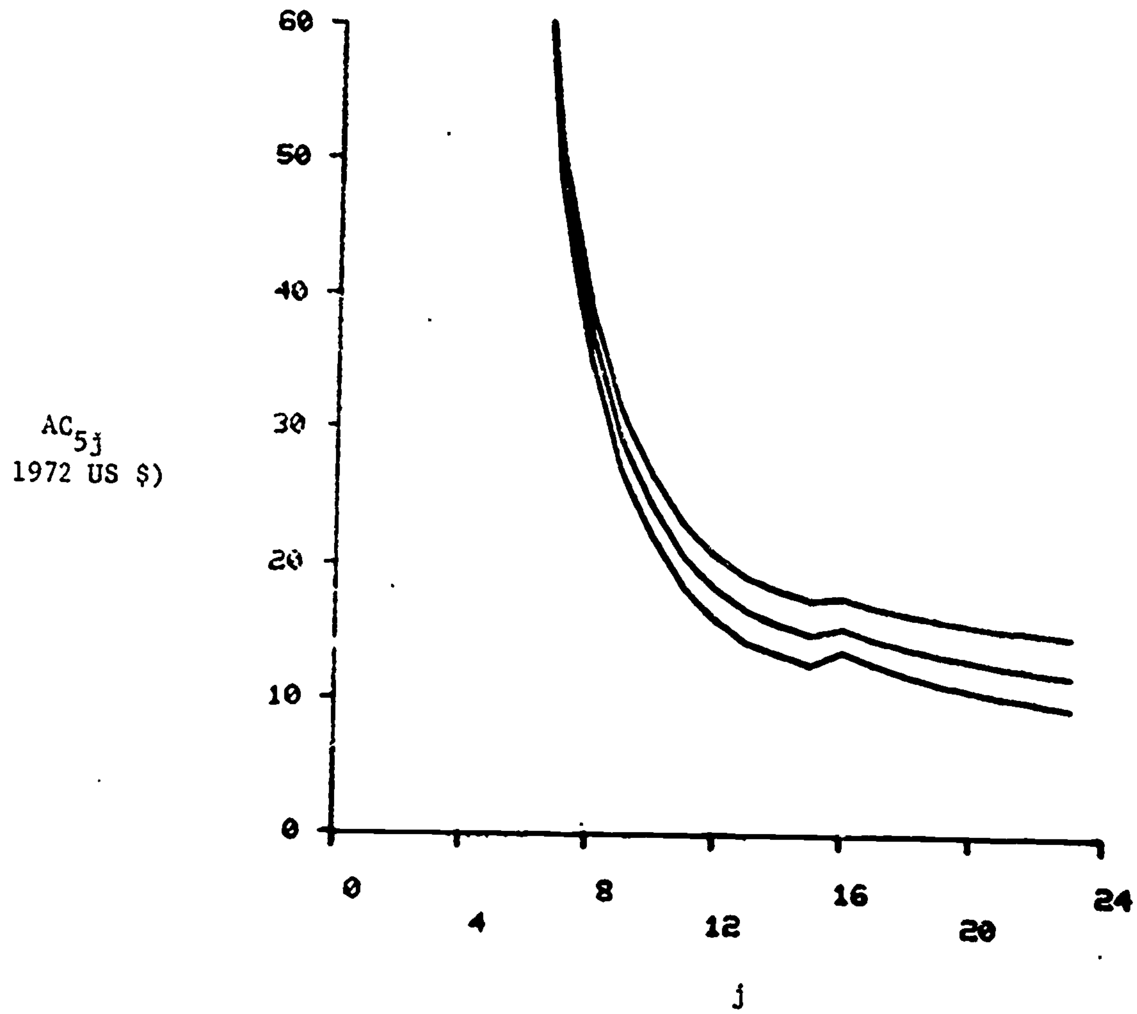

Fig. III.2: AC_{5j} for the Total Cost of Secondary in El Salvador (The top curve assumes a social discount rate of 15%, the middle 7.5%, and the bottom one 0.)

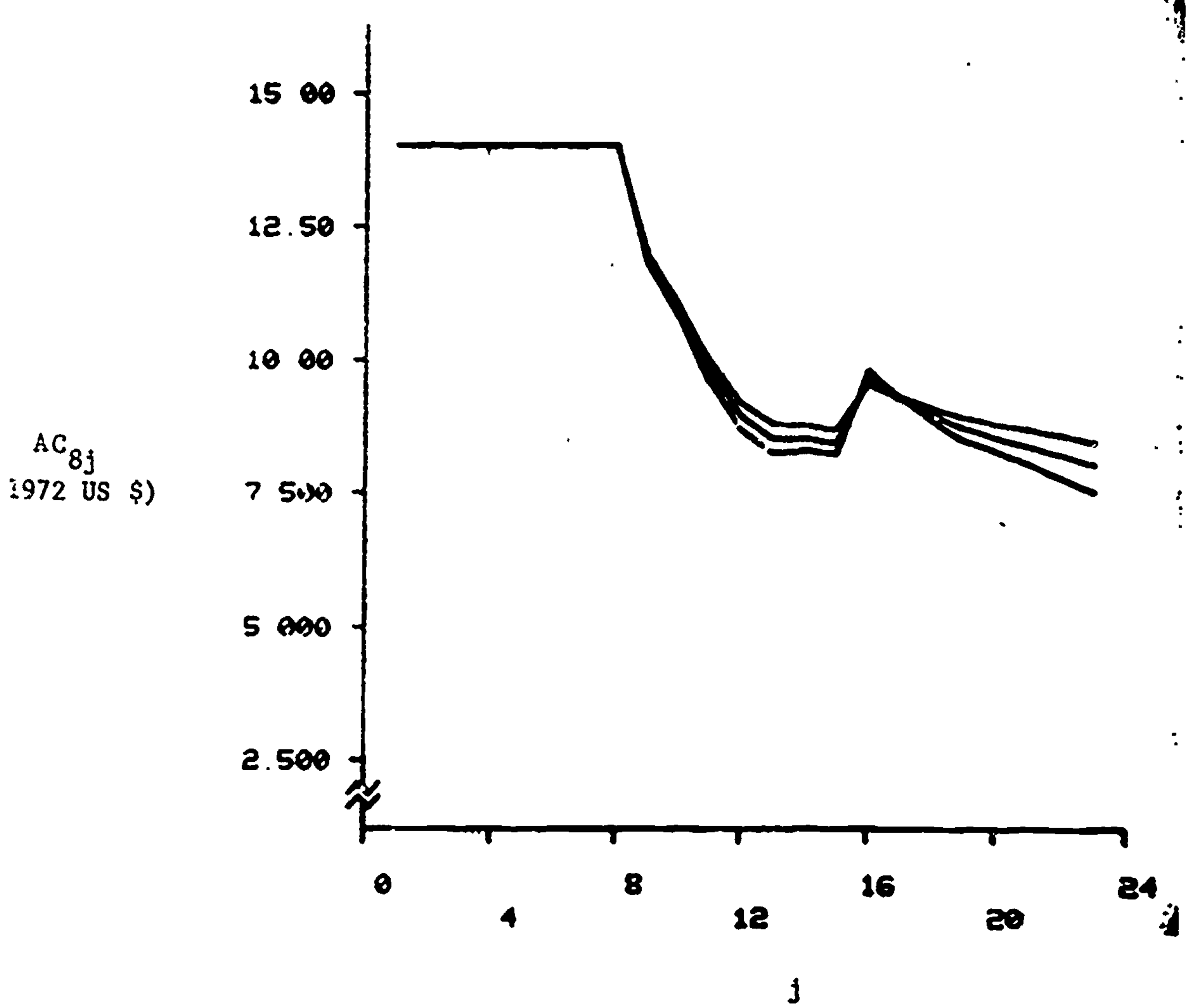

Fig. III.3: AC_{8j} for the Total cost of Secondary in El Salvador (The top curve assumes a social discount rate of 15%, the middle one 7.5%, and the bottom one 0.)

Table III. 5:

COSTS OF ITV IN THE IVORY COAST[a]
(thousands of 1972 U.S. Dollars)

	Year																					
	1969	1970	1971	1972	1973	1974	1975	1976	1977	1978	1979	1980	1981	1982	1983	1984	1985	1986	1987	1988	1989	1990
PRODUCTION																						
Facility	1050																					
Equipment	740	510	160								740	510	160									
Operations	460	1370	1560	1670	1750	1800	1860	1670	1560	1270	820	860	860	860	860	860	860	860	860	860	860	860
TRANSMISSION																						
Operations		30	190	220	250	270	310	330	330	330	340	340	340	340	340	340	340	340	340	340	340	340
RECEPTION																						
Equipment		560	550	660	740	1000	850	830	770	690	200	200	209	209	227	227	236	245	245	264	265	282
Replacement							480	480	590	670	900	1250	1340	1370	1520	1100	1450	1549	1579	1747	1127	1686
Maintenance Service		630	80	90	80	90	60	80	80	60	70	70	70	70	70	70	70	70	70	70	70	70
Operations			380	510	700	900	1120	1400	1620	1820	2030	2050	2070	2091	2112	2134	2154	2176	2198	2220	2242	2264
TOTAL COSTS	2250	3100	2920	3150	3520	4060	4680	4790	4950	4840	5100	5280	5049	4940	5129	4731	5110	5240	5292	5501	4904	5502
NUMBER OF STUDENTS (in thousands)			28	70	140	224	336	447	552	641	723	745	767	790	813	838	863	889	916	943	972	1001

[a]Footnote starts on next page.

Footnote to Table III.5

[a]Cost data are based on planning data given in Chau [1970] for 1969 to 1979. The relationales for each projection (1980-1990) or departure from their estimates are explained as follows:

Production facility. This assumes a 20 year lifetime.

Production equipment. This assumes a 10 year lifetime.

Production operations. This projection was made by IIEP.

Transmission operations. This projection was made by IIEP.

Reception equipment. After 1978 this expense grows proportionally to the following year's increment in student enrollment assuming an average class size of 44 and an average cost per receiver and antenna of $400.

Reception equipment replacement. This is based on the equipment cost stream shown above and an assumption of a five year life.

Reception maintenance service. This is based on IIEP. High initial set-up costs are followed by relatively constant costs that are more or less independent of the size of the system.

Reception operations. After 1979 this is assumed to remain fairly constant (increases at 1% per year) as more and more schools need not rely on batteries.

Number of students. After 1979 the student enrollment is assumed to grow at 3% per year.

The cost data presumably does not include teacher training, the development, distribution, or printing of student and teacher guides, nor provision for additional transmission equipment (the transmission time is taken from the existing stations which presently have excess capacity) that will be needed to cover the whole country (only 2/3 of the population is presently covered).

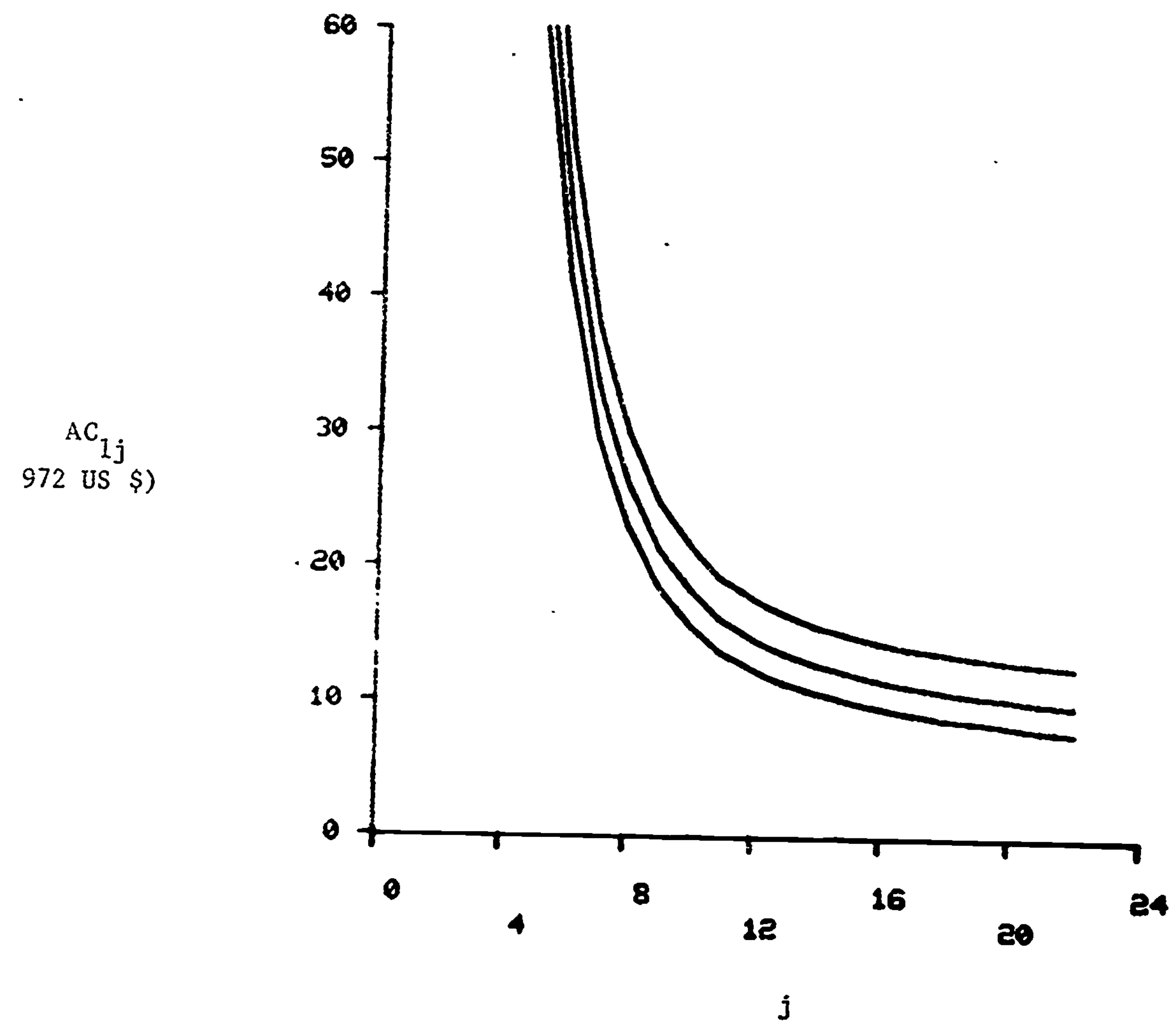

Fig. III.4: AC_{1j} for Elementary in the Ivory Coast
(The top curve assumes a social discount rate of 15%,
the middle one 7.5%, and the bottom one 0.)

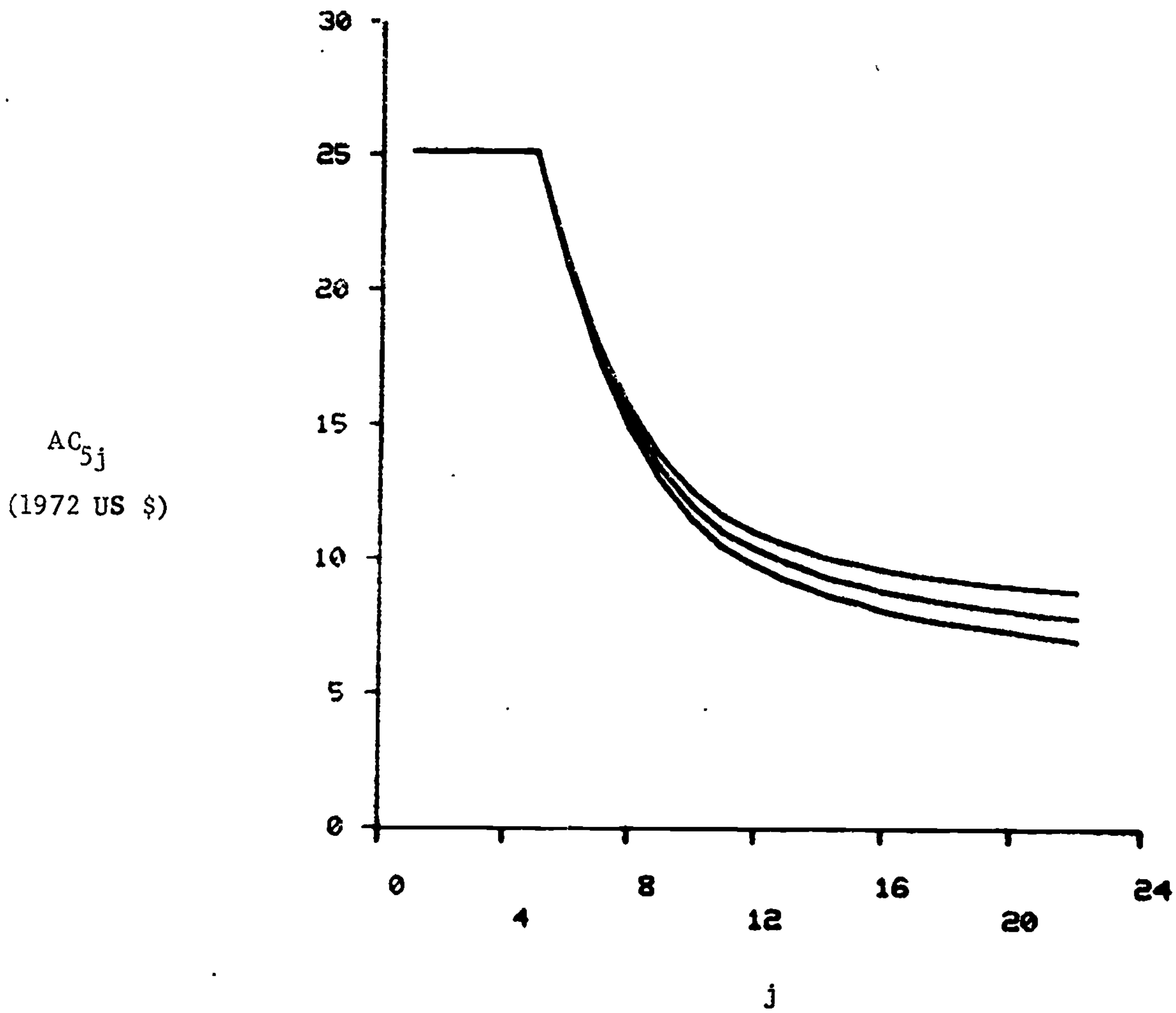

Fig. III.5: AC_{5j} for Elementary in the Ivory Coast
(The top curve assumes a social discount rate of 15%, the middle one 7.5%, and the bottom one 0.)

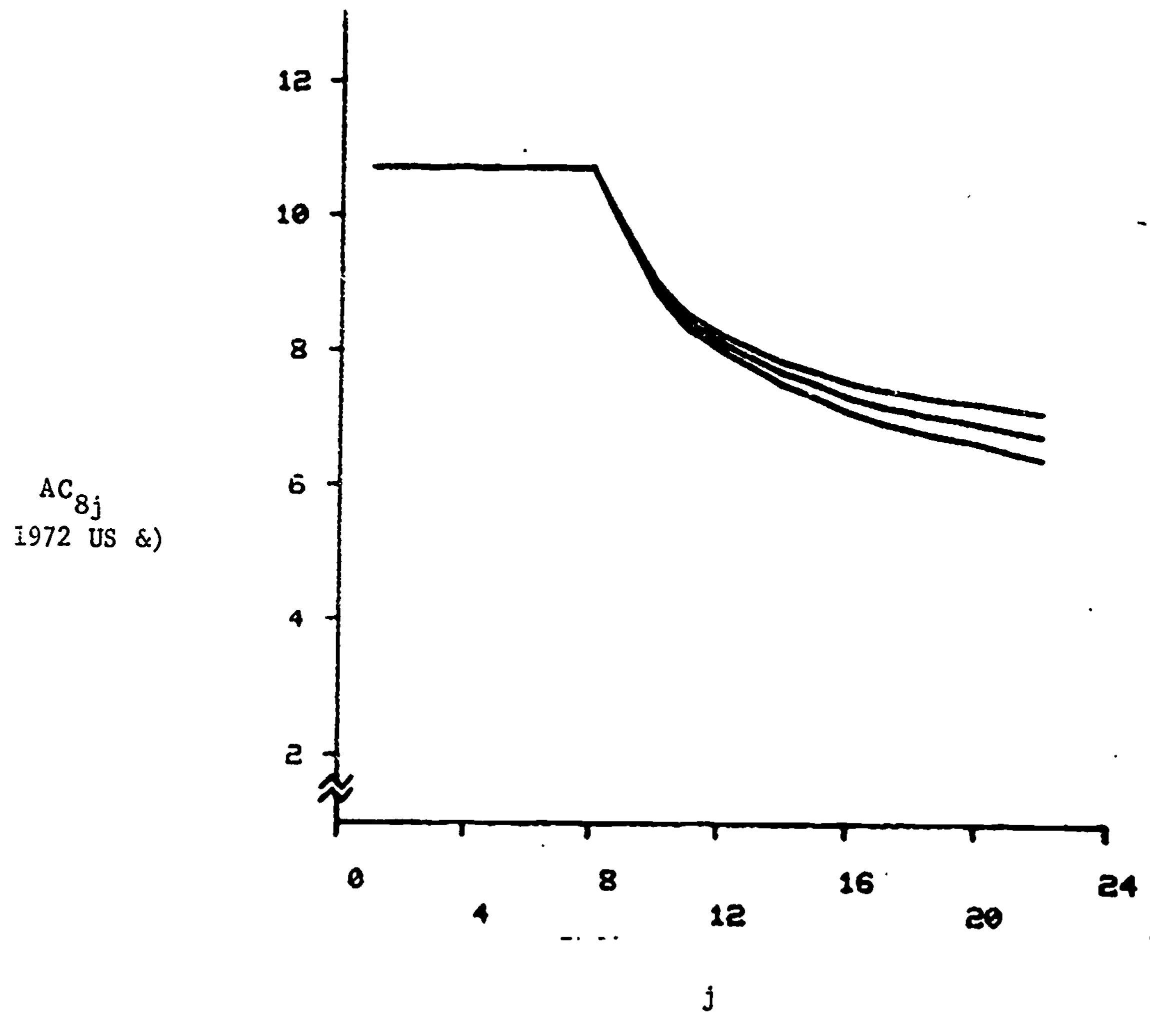

Fig. III.6: AC_{8j} for Elementary in the Ivory Coast
(The top curve assumes a social discount rate of 15%, the middle one 7.5%, and the bottom one 0.)

We turn now to derivation of cost functions for instructional radio and television. A concluding section will draw out the implications of those cost functions and these project studies.

IV. COST FUNCTIONS FOR INSTRUCTIONAL RADIO AND TELEVISION

Our purpose in this section is to identify the variables that will determine the cost of an instructional radio or television system, and to organize those variables into a total cost function in a way that will allow planners to examine the sensitivity of total cost to changes in the determining variables. The section has two parts. In the first we identify the variables determining cost and construct the total cost function in terms of them; the same format applies for both radio and television. In the second part we construct example cost functions for instructional radio and television.

A. Determinants of Total Cost

In constructing our total cost function we assume that total costs can be written as the sum of programming costs, transmission costs, reception costs, and book costs. (This assumption regarding functional form, though seemingly natural, is in some ways restrictive. It fails to allow, for example, for tradeoffs between transmission and reception costs; this particular tradeoff plays a central role in assessing the economic desirability of satellite transmission.) Each of the four costs we consider is assumed to be a function of some of the components of a vector, D , of determining variables.

We thus assume the following form for our total cost equation:

$$TC(D) = C_P(D) + C_T(D) + C_R(D) + C_B(D) , \qquad (4)$$

where the subscripts P , T , R , and B refer to programming, transmission, reception, and book costs. Our approach to specification of TC(D) will be to examine each of the component cost functions in turn. First, however, we list the determining variables we use with their definitions. This is done in Table IV.1.

Insert Table IV.1 about here

<u>Programming cost function</u>. For this analysis we simply treat programming costs as capital costs. A more detailed analysis would examine how the cost of studio facilities and personnel requirements would vary with production rate for differing quality programs. Here we simply summarize those costs into c_q , the cost of producing an hour of programming of quality level q , and annualize the initial program preparation costs. The total number of hours of programming required is equal to gh ; thus the cost of programming equation becomes:

$$C_p(D) = a(r,n_p)ghc_q \ , \qquad (5)$$

where $a(r,n_p)$ is the annualization factor (equation 2, Section II). C_p is written as a function of D since D comprises all determining variables, including r, n_p, g, h, and c_q . (That $C_p(D)$ does not depend on other variables in D makes no difference; we find it notationally convenient to use D as the vector of determining variables for each component cost equation.)

Equation 5 assumes that the target audience speaks a single language; in a multi-lingual nation like India allowance must be made for the cost of providing regional versions of the programs. Transmission and book costs may be affected as well.

<u>Transmission cost function</u>. The transmission cost function, $C_T(D)$, is given by:

$$C_T(D) = \sum_{i=1}^{k} [a(r,n_T)\ c_T(A_i) + c_m(A_i)] \ . \qquad (6)$$

The sum is over the costs for each of the k transmitting stations; the meaning of the terms within the brackets is self-explanatory in

Table IV.1: Components of the Vector D of Determining Variables

Variable		Definition
A. System Variables		
1.	N	number of students using the system each year.
2.	g	number of grade levels served.
3.	h	average number of hours of programming received by each student in the course of a year.
4.	k	number of distinct geographical regions served.
5.	A_i	area (in $km.^2$) of the ith geographical region to be served.
6.	q	measure of quality of program materials.
7.	p	number of pages of printed material provided for each student per hour of program broadcast.
8.	s	number of students who share a receiver (this will depend itself on class size and the number of classes that can share a receiver).
9.	e	fraction of receivers located in an electrified area.
B. Cost Variables		
10.	c_q	cost per hour of program production of material of quality q .
11.	$c_T(A_i)$	cost of purchasing, installing and providing a building for a transmitter, tower, and antenna capable of serving an area of A $km.^2$ This also includes the cost of an inventory of program tapes.

Table IV.1 (cont.)

12.	$c_m(A)$	annual cost of power, maintenance, and operating personnel for a transmitter capable of reaching A $km.^2$.
13.	c_R	cost of installing one receiver, including building modifications required for lighting, security, etc.
14.	c_e	capital cost per receiver of power generating equipment (required only for TV in non electrified areas). This equipment is assumed to have the same lifetime as a receiver.
15.	c_p	cost of electric power, per receiver per hour, using the available power supply. (A more detailed analysis would provide a higher value of this parameter for non electrified areas because, even after capital costs are paid, power costs more from local generators.)
16.	c_B	cost of books, per page.
C. Capital Lifetime Variables		
17.	n_p	life of a completed program.
18.	n_T	life of the transmitter installation (a more detailed analysis would separate out building costs).
19.	n_R	life of a receiver (including consideration of the probability of its being stolen).
20.	n_B	life of a book.
D. Social Rate of Discount		
21.	r	social rate of discount.

terms of the definitions of Table IV.1. Interconnection costs are not considered here because each location is assumed to have a sufficient store of taped programs. c_T includes the cost of the tape inventory. A more detailed analysis would examine the tape inventory cost explicitly, as a function of gh , and consider the alternatives of microwave interconnection or mailing and reusing tapes.[18]

Reception cost function. The total number of receivers required is N/s . The total number of receivers requiring an auxiliary power supply is (1-e)N/s . The number of hours per year of receiver use will equal hN diveded by the average class size, here assumed to equal 35.

The receiver cost function is, then, given by:

$$C_R(D) = a(r,n_R)Nc_R/s + a(r,n_R)(1-e)Nc_e/s + hNc_p/35 \; . \quad (7)$$

The first term on the right hand side is the annualized receiver cost; the second term is the annualized capital cost of the auxiliary power supply; the third term is the operating cost of the electrical power. We assume the second term would be irrelevant for radio since battery supplies could be used.

Book cost function. The total number of book pages required per year is Nhp ; the book cost equation is, then:

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[18] Still another distribution mechanism is through use of communication satellites to broadcast instructional radio or television directly to low cost receivers in rural areas. The ASCEND [1967] study at Stanford University examined the viability of satellite broadcast television for Brazil, India, and Indonesia. Dunn, Lusignan, and Parker [1972] and Polcyn et al. [1972] provide more up to date estimates of satellite and ground station costs. Jamison, Jamison, and Hewlett [1969] suggested a number of advantages for using a satellite to distribute multiple radio channels instead of television, and provided initial cost estimates for this possibility; Spain, et al. [1972, Chapter VI] provide more recent estimates of the cost of a multiple radio channel capability.

$$C_B(D) = a(r,n_B)Nhpc_B \;. \qquad (8)$$

Cost function recapitulation. In equations 5, 6, 7, and 8 we have detailed how programming, transmission, reception, and book costs vary as a function of the determining variables listed in Table IV.1. The total cost equation, equation 4, is simply the sum of equations 5, 6, 7, and 8. Even though we consider 21 separate determining variables, our cost function represents only an approximation; at a number of points along the way we have indicated where more detail could be provided and other instances will have occurred to the reader. Nevertheless, we feel equation 4 to be a useful approximating equation for broad planning purposes (or overall system cost-effectiveness analysis), and we illustrate its use in the next subsection. After the broad outlines of a system have been decided upon, a detailed planning effort would be required to obtain much more specific cost information (with expenditures structured in time), and to engage in detailed cost optimization.

It is perhaps worth pointing out that the cost function of equation 4 fits into the simple $TC(N) = F + VN$ format if one takes as given all the determining variables except N. The programming and transmission costs are fixed; the reception and book costs are variable. We thus have:

$$F = a(r,n_p)ghc_q + \sum_{i=1}^{k} [a(r,n_T)c_T(A_i) + c_m(A_i)] \;, \qquad (9)$$

and

$$V = a(r,n_R)c_R/s + a(r,n_R)(1-e)c_e/s + hc_p/35 + a(r,n_B)hpc_B \;. \qquad (10)$$

The expression for V is, of course, obtained by summing equations 7 and 8 and dividing by N. An advantage of displaying the cost function parameters F and V as themselves functions of the various determining variables is that it allows the possibility of examining the sensitivity of TC, F, or V to any of the determining variables by taking the appropriate partial derivatives.

B. Example Use of Total Cost Equation

Table IV.2 shows the values we assume for each determining

Insert Table IV.2 about here

variable in this example, for both radio and television. The numbers there are meant to be realistic, though a search for minimum cost solutions could probably improve on them.

Using those numbers we obtain annualized total costs from equations 6, 7, 8, and 9. Assuming a social rate of discount of 7.5%, the cost are as follows.

Cost Element	Radio	Television
C_P	\$25,560	\$184,070
C_T	37,589	100,976
C_R	27,838	299,103
C_B	35,828	26,871
TC	126,815	611,020
TC/N	.63	3.06

The above, then, give total annualized costs and average annualized costs. The cost of television is 4.85 times that of radio, almost half a million dollars per year more than radio's \$127,000. The costs per student hour follow from dividing TC/N by h, here assumed to equal 120. The cost per student hour of radio is .53¢; of television, 2.55¢.

The total cost functions for radio and television can be obtained from equations 9 and 10, and allow examination of the relation between marginal and average cost (AC/V). The total cost functions are as follows, with values of AC/V shown for N = 200,000.

Table IV.2: Example Values of Cost Components

Variable		Assumed Value for Radio	Assumed Value for TV
1.	N	200,000	200,000
2.	g	4	4
3.	h	120	120
4.	k	1	1
5.	A	15,400 $km.^2$ (70 km. radius)	15,400 $km.^2$
6.	q	moderate quality	moderate quality
7.	p[a]	2	1.5
8.	s	70	70
9.	e	-	.50
10.	c_q[b]	$250.	$1800.
11.	c_T[c]	$153,000	$411,000
12.	c_m[d]	15,300	41,100
13.	c_R	$20	$175
14.	c_e[e]	-	$400
15.	c_p	$.02	$.05
16.	c_B[f]	$.0025	$.0025
17.	n_p	6	6
18.	n_T	10	10
19.	n_R	5	5
20.	n_B	4	4
21.	r	7.5%	7.5%

Footnotes to Table IV.2

[a]Radio is assumed to require 33% more printed material than television because of the television's capability to display visual images.

[b]The program production costs used here are approximately equal to those for radio in Thailand (Schramm, et. al. [1967], after inflationary adjustment) and for television in Samoa. The television costs fall within the range from minimum to high quality production costs used by Sovereign [1969].

[c]These estimates are from the General Learning Corporation [1968] study of instructional media system costs. A summary of the TV transmission costs appears in vol. II, p. 112, and includes antenna, tower, transmitter, test equipment, building, site preparation and land costs. The radio transmission costs are for quality FM broadcast to approximately the same area and the estimates appear in vol. II, p. 226. The radio estimates there appeared to exclude land costs, so the value used in this table was increased to allow for land purchase. It should be emphasized that there are wide variations in equipment cost estimates; we have used conservative estimates here. Butman [1972] uses a substantially lower figure of $35 per square mile for TV transmitter costs; Broadbent, et. al. [1966] have slightly lower estimates still; and Bourret [1971] has presented a design for very low cost TV transmitters. Polcyn, et. al. [1972] further discuss component costs for educational technology systems and describe in some detail the cost estimates of an instructional radio station.

[d]These are 10% of line 11.

[e]See Butman [1972, p. 30]; power supplies for television in non-electrified areas of the Ivory Coast appear, however, to be costing substantially more than this.

[f]See Appendix C.

Radio: $TC(N) = \$63{,}150 + .32N;\ AC/V = 1.98$.

Television: $TC(N) = 284{,}046 + 1.63N;\ AC/V = 1.88$.

The total cost equations and costs per student hour in this example fall close to the values obtained in Section III from ongoing project information; while lower costs are probably feasible with careful planning, the values in this example illustrate what might be expected at present.

V. CONCLUSIONS

In this paper we have described a consistent methodology for evaluation of the costs of instructional radio and television, and applied that methodology to analysis of the cost of a number of projects. We obtained annualized costs for 5 instructional television and 3 instructional radio projects; for two of the television projects, time streams of costs and expenditures were available, and we used this information to examine the time structure of average costs. Finally, we developed general cost equations for use in planning educational technology projects, and applied those equations to evaluate costs of realistic example television and radio projects.

A number of conclusions emerge from our analysis:

1. It is realistic to expect the costs of instructional television to range from 1.5¢ to 15¢ per student per hour, depending most importantly on the number of students in the system. The low end of this range can only be reached if close to a million students are using the system in a reasonably compact geographical area.

2. It is realistic to expect the costs of instructional radio to range from 1/3¢ to 3¢ or 4¢ per student per hour, about one fifth as much as instructional television. The high end of this range can be reached with very small numbers of students (several thousand); the low end might require several hundred thousand.

3. Cost estimates respond reasonably sensitively to the social rate of discount; going from a 0 to a 15% social rate of discount can increase annualized cost estimates by 15% to 40%.

4. The heavily front-loaded costs and rear-loaded utilization of technology projects results in a requirement that projects last 10 to 20 years to allow unit costs to fall to a reasonable level. This is vividly illustrated through examination of 'average costs from i to j', our AC_{ij}s . If there is a substantial probability that a project will not last 15 years, its initiation should be reconsidered. Once into a project, future AC_{ij} values are much lower than prior to its initiation, as one would expect.

Our analysis provides only the cost side of the input to a cost-effectiveness analysis of the potential role of instructional television and radio in developing countries. Yet the surveys of Chu and Schramm [1967], Schramm [1973], and Jamison, Suppes, and Wells [1973] indicate that these media are good substitutes for conventional instruction of reasonably high quality. For these reasons we can expect to see an expanding role for the new media, as substitutes for conventional inputs, as the media prices continue to decline relative to that of conventional instruction.

March, 1973

APPENDIX A: THE COST OF PRINTED MATERIAL

An important fraction of the cost of instructional radio or television systems can be in the provision of the accompanying printed material[4]. In this Appendix we provide estimates of the cost of providing printed materials to schools; first we examine the cost of providing a high quality hardbound book, then we examine information on the cost of workbook quality material. We stress that the estimates in this Appendix are for the purpose of getting a general picture of what costs are possible; analysis for any particular country would need to look in detail at local costs and opportunities. The book costs we present are those for production in Taipei, Republic of China, and probably reflect the minimum feasible costs.

Table A.1 provides a detailed breakdown of the cost of

Insert Table A.1 about here

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producing a high quality 500 page hardbound book in Taipei and of shipping the book 4000 miles. The costs are recent (late 1972) estimates from a printer in Taipei, and include his profits. The costs do not include typesetting, and assume that the material to be printed is in a form suitable for photo-reproduction. It should be kept in mind that these set-up costs can be significant for small runs. Figures in that table are in New Taiwan dollars (NT $) of which there are 40 to a U.S. dollar. Production in quantities of 1500 results in a price of less than $1.60 per copy or $.0031 per page. The authors have handled books produced by this printer at the quoted price and the quality is high indeed. One of the authors purchased a lower quality 2 volume set (totaling 1800 pages) at a bookstore in Taipei about two years ago at a per page cost of $.0014. It should be stressed that at a production level of 1500 copies most

Table A.1: Cost of Book Production in Taipei, Republic of China[a,b]

Item	Comment
1. Quantity:	1,500 copies
2. Number of pages:	500 pages
3. Size:	6" x 9" (Thickness about 1-1/2")
4. Cost of Printing and Paper:	By photo-offset, printed in black and white Paper - 80 lb. woodfree (NT $441.00 per ream NT $441.00 x 40 reams = NT $27,609.00) NT $0.040 per page NT $0.040 x 500 pages = NT $20.00 per copy
5. Binding:	Sewn in cloth bound NT $17.00 per copy
6.. Book Dust Jacket:	NT $2.00 per copy (optional)
7. Plastic Waterproof Packing Bag:	NT $2.00 per copy (optional)
8. Factory Price:	4 + 5 + 6 + 7 NT $20.00 + NT $17.00 + NT $2.00 + NT $2.00 = NT $41.00 per copy or U.S. $1.025 per copy NT $41.00 x 1,500 copies = NT $61,500.00 = US $1,537.50
9. Packing:	Packed in export standard carton boxes Each carton contains 20 copies NT $20.00 per carton or equivalently NT $1.00 per copy.
10. Freight:	NT $2.50 per copy from Taiwan to U.S. West Coast
11. Miscellaneous:	Inland transportation, custom broker, loading charges, insurance, and handling charges, etc. NT $3.50 per copy.
12. Total Price:	8 + 9 + 10 + 11 NT $41.00 + NT $1.00 + NT $2.50 + NT $3.50 = NT $48.00 per copy or U.S. $1.225 per copy.

[a]Prices in this table are expressed in New Taiwan Dollars (NT $). In 1972 NT $40. = U.S. $1.

[b]Source: Price quotations from a Taipei printer, 1972. (We have received information as the final draft of this paper was being prepared, in March 1973, that inflation in Tiawan and devaluation of the dollar have resulted in approximately a 25% increase in the U.S. dollar prices that are indicated in this table.)

economies of scale have been realized; the price per copy would drop only about 2% if the production level were doubled to 3000 copies.

The price per page is, however, rather sensitive to the number of pages per volume because of relatively large fixed binding and handling charges. From information in table A.1 we can derive the following approximate cost equation for the cost, C_v , of a volume having P pages (with P between 250 and 750). Costs are expressed in U.S. dollars, and are increased 25% from what the table would indicate for the reason noted in footnote b of the table.

$$C_v(P) = .94 + .00125\,P\ .$$

The cost per page, C_p , is simply $C_v(P)/P$; for a 250 page volume C_p is \$.005 and for a 750 page volume C_p is \$.0025.

We have less up to date information available concerning the price of workbooks. M. Jamison [1966, pp. 76-80] surveyed printing costs at that time and concluded that a 250 page paperbound workbook with 8 1/2" by 11" pages would cost less than \$.00167 per page. This is approximately 40% of the cost estimated above for a high quality hardback of equal length. This \$.00167 was estimated on what the author felt to be conservative assumptions, and he cites a study of Wilson, Spaulding, and Smith [1963] that concluded that there exist abundant, now wasted, raw materials for paper in developing countries that could be used as inputs to the production of very low cost workbooks.

We conclude this Appendix with some brief comments concerning the decision whether, for a particular course, a school system should furnish each child workbooks or loan him a hardbound text. Let $C_B(P)$ be the cost of a hardbound book of length P and $C_W(P)$ be the cost of a workbook of length P . Assume that a year long course requires P_B book pages or P_W workbook pages, that the expected useful lifetime of the book is n years, and that the social rate of discount is r . From equation 2 of Section II the annualized cost of the book is $a(r, n)C_B(P_B)$; if this number is greater than $C_W(P_W)$ the workbook should be chosen. If, on the other hand, the cost of the workbook is greater the matter is not so simple. There may well be advantages to letting the child own, write in, and take home his own workbook. If so a judgment must be made concerning whether the greater cost of the workbook justifies the additional benefits.

APPENDIX B: THE COST OF COMPUTER MANAGED INSTRUCTION

Computer managed instruction (CMI) individualizes the instruction a student receives by preparing periodic printouts for him (or his teacher) that contain individualized problem sets, corrections to previous problems, and perhaps individualized study suggestions or reading assignments. Baker [1971] described the activities of a number of ongoing CMI projects in the U.S., and readers interested in obtaining a feel for the variety of uses to which CMI has been put should see that paper.

CMI is probably too costly to be viable today in a developing country, yet by moving the student away from the on-line interaction with a computer that computer-assisted instruction (CAI) provides, CMI costs can come to less than $.10 per student per hour, less than some instructional television projects. The cost of CAI ($.85-$1.50 per student per hour) rules that medium out entirely for cost-effective utilization in a developing country -- see Jamison, Suppes, and Butler [1970] or Ball and Jamison [1973] for analysis of CAI costs.

As with all educational systems that utilize a substantial capital component, the cost per student of CMI is sensitive to the number of students utilizing it. However, with the CMI system costed here, most, but not all, of the economies of scale are reached with 10,000 to 20,000 students utilizing the system. Costs are examined for both a developmental system and for an operational system that would be based upon it. The costs we provide are for a particular system and for that reason should only be considered illustrative of the possibilities.

All component costs used in these computations are estimates from the Computer Curriculum Corporation of Palo Alto, California. The cost computations assume that each student receives 100 lessons per year and that each lesson is 3 pages long. Such a lesson would take approximately one half hour for the student to complete. The student would respond on a specially printed IBM card, using one per lesson. In order to allow for paper and card wastage, all requirements for these items are increased 50%. Each student's lessons are generated in a stand-alone computer, printed on a line printer, then distributed to his school. His responses are recorded on the IBM card which is returned and read into the computer so that the student's next lesson takes into account his recent past performance. Each line printer costs about $14,000 installed and the computer system costs about $70,000 installed. The line printers can each print about 2000 three page lessons per day and the computer can handle at least four line printers.

Two systems are costed here; System 1 uses a single line printer and System 2 uses four. Each line printer is assumed to be in use for 200 days per year. System 1 thus generates 400,000 lessons per year and System 2 generates 1,600,000. Since each student uses 100 lessons per year, System 1 would serve 4000 students and System 2 would serve 16,000. Table B.1 details the costs involved.

Insert Table B.1 about here

Section IV of table B.1 gives the final figures for the two systems. System 1 has an effective annual total cost of 89,220 per year, a cost of $22.30 per student per year, and a cost of $.22 per lesson. System 2 has an effective annual cost almost twice that of System 1 -- $150,480 -- but by serving four times as many students is able to reduce per student annual costs to $9.40. The cost per lesson for System 2 is $.09, perhaps twice the hourly cost of ITV. System 2 is, essentially, the operational version that could evolve from experimentation with System 1; System 1 could at any time be converted to System 2 by purchasing the additional line printers or a separate implementation of CMI could begin immediately with System 2.

As a final comment on costs it should be noted that the primary justification for CMI is not cost reduction; the justification

Table B.1: Cost of Computer Managed Instruction[a]

I. Capital Costs			
1. System 1 hardware (Central processor, card reader, 1 line printer)	$ 73,000		
2. Shipping and installation	11,000		
TOTAL, System 1	$ 84,000		
Equivalent annual cost,[b] System 1		($15,960)	System 1
3. Three additional line printers for System 2, at $14,000, installed	42,000		
TOTAL, System 2	$126,000		
Equivalent annual cost, System 2		($23,940)	System 2
II. Fixed Recurrent Costs (Independent of the number of printers or students)			
1. maintenance engineer (including housing allowance, etc.)	35,000		
2. parts and miscellaneous	16,000		
3. curriculum use charge	4,500		
TOTAL, Fixed Annual Costs		($55,500)	System 1 or 2
II. Variable Recurrent Costs (Dependent on number of students, N)			
1. 450 sheets of printout per student at a cost for paper and ribbon of $.006 per sheet	$2.70xN		
2. 150 IBM cards per student at $.00167 per card	.24xN		
3. cost of transporting printout and cards to schools, estimate	1.50xN		
TOTAL	$4.44xN		
Variable annual cost, System 1 (N=4000)		($17,760)	System 1
Variable annual cost, System 2 (N=16,000)		($71,040)	System 2
IV. Total and Per Student Costs			
1. Total Annual Cost, System 1 (includes annualization of initial costs)	$ 89,220		
1'. Total Annual Cost, System 2 (includes annualization of initial costs)	$150,480		

Table B.1: (cont.)

2.	Cost per student per year, System 1	\$ 22.30
2′.	Cost per student per year, System 2	\$ 9.40
3.	Cost per lesson, System 1	\$ .22
3′.	Cost per lesson, System 2	\$ .09

[a] Source: Cost estimates from Computer Curriculum Corporation, Palo Alto, California in 1972.

[b] Capital costs are annualized by use of equation (2), Section II, under the assumption of an 8 year equipment lifetime and a 10% social rate of discount.

is quality improvement. As the cost per student per years depends directly on the number of lessons received, and the amount of quality improvement may well increase at a decreasing rate with number of lessons received, it will be important to experiment with differing numbers of lessons in order to provide the information necessary for an informed cost-effectiveness analysis of the potential for this medium. At the present our knowledge of CMI effectiveness is sufficiently slight that any cost-effectiveness analysis of its role would be undertaken with substantial uncertainty.

APPENDIX C: OPPORTUNITY COST OF INSTRUCTIONAL TECHNOLOGY

A slightly different notion of cost than that used in the text is the occasionally useful notion of <u>opportunity cost</u>. The opportunity cost of a choice from among a limited set of alternatives is the value to the decision-maker of what he turned down in order to be able to choose what he did. If, for example, the superintendent tells a principal that he can either have two new teachers or a science laboratory and the principal chooses the teachers, the opportunity cost to him of the teachers was a science laboratory.

If a school system's per student expenditure is constrained by a fixed budget, then having more of any one thing implies there must be less of something else. For this reason, it may be useful to a decision-maker to see explicitly what these opportunity costs are for certain important categories of alternatives. Since the largest expenditure category for schools is presently teacher salaries, we will examine the opportunity cost of introducing something new (e.g., instructional television or radio) under the assumption that its opportunity cost is less teacher input. Let S be the student to teacher ratio (this is not necessarily the same as class size; it also depends on the relative amount of time students and teachers spend in school) before the technology is introduced, and let W be the teacher's annual wage. Let A equal the average annual cost of the technology and let I be the increase in class size required to make the post-technology per student instructional cost equal to R times the pre-technology instructional cost of W/S. Neglecting the minor influence of changes in S on A, the post-technology instructional cost equals $[W+A(S+I)]/(S+I)$ and the following must hold:

$$W/S = R[W + A(S+I)] / (S+I) .$$

To find the increase in student-to-teacher ratio required to pay for the introduction of the technology, the above equation is solved for I giving:

$$I = [SW(1-R) + AS^2R] / [W-ASR] . \qquad (C.1)$$

I represents, then, the opportunity cost of introducing a technology in terms of increased student to teacher ratio. Under the assumption that per student costs remain unchanged, i.e., R = 1 , Table C.1 shows values of I for several values of A and W , and for values of S equal to 25 and 40. If, for example, S = 25, W = $1500, A = $9.00, and R = 1 Table C.1 shows that I = 4.41; that is, the student to teacher ratio after technology is introduced equals 29.41. While the formula of equation C.1 was developed for

Insert Table C.1 about here

expressing the opportunity cost of introducing a technology in terms of student to teacher ratio, similar formulas could be developed between other pairs of inputs. All such formulas would essentially represent ways of analytically evaluating the tradeoffs within a fixed budget constraint.

Table C.1:

Increase in Student to Teacher Ratio Required to Finance Technology[a]

	A	W = teacher annual wage			
		$750	$1500	$2250	$3000
$S^b = 25$					
	$ 1.80	1.60	0.77	0.51	0.38
	$ 4.50	4.41	2.03	1.32	0.97
	$ 9.00	10.71	4.41	2.78	2.03
	$18.00	37.50	10.71	6.25	4.41
$S^b = 40$					
	$ 1.80	4.25	2.02	1.32	.98
	$ 4.50	12.63	5.45	3.48	2.55
	$ 9.00	36.92	12.63	7.62	5.45
	$18.00	-	36.92	15.24	12.63

[a]This table shows the increase in average student to teacher ratio that is required if per student instructional costs (teacher cost plus technology cost) is to remain unchanged after a technology costing A dollars per student per year is introduced into the system. The values of A chosen reflect costs per student per day of $.01, $.025, $.05, and $.10 if the school year is 180 days.

[b]S is the value of the student to teacher ratio before the technology is introduced.

APPENDIX D: SUPPLEMENTARY TABLES FOR EL SALVADOR

Tables D.1 to D.12 on the following pages show the values of

Insert Tables D.1 to D.12 about here

AC_{ij} for the El Salvador television project. D.1 through D.3 show values assuming secondary school use only and give AC_{ij}s based on total cost for interest rates of 0, 7.5%, and 15%; D.4 through D.6 give the costs incurred by the Government of El Salvador (GOES). Tables D.7 through D.12 cover the same information assuming use by the elementary school system as well as secondary.

Section II.C of the text describes the definition of the AC_{ij} terms and Section III.B discusses the El Salvador data further.

Table D.1:

AVERAGE TOTAL COSTS FROM YEAR i TO YEAR j -- EL SALVADOR[a]
Secor y School Only
Interest Rate = 0

FROM YEAR i	TO YEAR j										
	1968	1970	1972	1974	1976	1978	1980	1982	1984	1986	1988
1966	∞	235.63	74.79	38.27	24.49	18.26	15.56	14.92	13.10	11.87	10.82
1969		131.25	57.40	30.94	20.50	15.63	13.62	13.41	11.87	10.86	9.95
1971			42.63	23.37	16.09	12.64	11.41	11.69	10.46	9.67	8.94
1972			17.92	13.36	10.59	8.98	8.73	9.64	8.78	8.26	7.74
1973				11.70	9.50	8.19	8.16	9.25	8.44	7.97	7.47
1974				9.75	8.45	7.45	7.66	8.94	8.16	7.72	7.25
1975					7.96	7.04	7.43	8.88	8.06	7.62	7.15
1976					6.95	6.47	7.15	8.85	7.97	7.51	7.04
1977						6.24	7.20	9.13	8.08	7.56	7.05
1978						6.51	7.59	9.71	8.35	7.72	7.13
1980							7.89	11.12	8.68	7.79	7.07
1984									5.21	5.59	5.29
1988											4.74

[a]The costs are in 1972 U.S. Dollars.

Table D.2:

AVERAGE TOTAL COSTS FROM YEAR i TO YEAR j -- EL SALVADOR[a]
Secondary School Only
Interest Rate = 7.5%

	TO YEAR j										
FROM YEAR i	1968	1970	1972	1974	1976	1978	1980	1982	1984	1986	1988
1966		254.95	82.72	44.49	29.84	23.11	20.01	18.88	17.14	15.95	14.97
1969		134.63	60.50	34.24	23.71	18.73	16.53	15.96	14.59	13.67	12.89
1971			43.71	24.90	17.75	14.35	13.02	13.00	11.99	11.33	10.75
1972			17.92	13.55	10.95	9.45	9.15	9.80	9.18	8.80	8.44
1973				11.78	9.69	8.46	8.37	9.21	8.64	8.31	7.98
1974				9.75	8.52	7.58	7.73	8.77	8.23	7.92	7.61
1975					8.00	7.12	7.43	8.66	8.08	7.77	7.45
1976					6.95	6.48	7.09	8.58	7.95	7.63	7.30
1977						6.23	7.13	8.90	8.11	7.72	7.34
1978						6.51	7.55	9.57	8.47	7.96	7.50
1980							7.89	11.17	8.98	8.15	7.53
1984									5.21	5.58	5.32
1988											4.74

[a]The costs are in 1972 U.S. Dollars.

Table D.3:

AVERAGE TOTAL COSTS FROM YEAR i TO YEAR j -- EL SALVADOR[a]
Secondary School Only
Interest Rate = 15%

	TO YEAR j										
FROM YEAR i	1968	1970	1972	1971	1976	1978	1980	1982	1984	1986	1988
1966		275.36	91.47	51.61	36.25	29.21	25.87	24.44	22.85	21.79	20.99
1969		137.95	63.62	37.70	27.24	22.32	20.07	19.29	18.13	17.36	16.77
1971			44.72	26.42	19.48	16.21	14.87	14.67	13.87	13.35	12.93
1972			17.92	13.74	11.29	9.92	9.60	10.04	9.61	9.35	9.12
1973				11.85	9.87	8.73	8.61	9.24	8.84	8.62	8.41
1974				9.75	8.59	7.71	7.80	8.64	8.26	8.06	7.87
1975					8.04	7.19	7.44	8.47	8.07	7.86	7.66
1976					6.95	6.49	7.04	8.34	7.89	7.67	7.46
1977						6.22	7.06	8.67	8.08	7.80	7.54
1978						6.51	7.52	9.42	8.54	8.14	7.80
1980							7.89	11.21	9.22	8.50	7.97
1984									5.21	5.58	5.34
1988											4.74

[a] The costs are in 1972 U.S. Dollars.

Table D.4:

AVERAGE GOES COSTS FROM YEAR i TO YEAR j -- EL SALVADOR[a]
Secondary School Only
Interest Rate = 0

	TO YEAR j										
	1968	1970	1972	1974	1976	1978	1980	1982	1984	1986	1988
FROM YEAR i											
1966	∞	162.50	38.65	21.64	15.43	12.29	11.23	11.63	10.49	9.76	9.07
1969		70.00	23.23	15.15	11.89	9.96	9.51	10.29	9.41	8.85	8.30
1971			13.88	11.01	9.57	8.40	8.37	9.42	8.69	8.25	7.79
1972			11.25	9.81	8.86	7.89	8.01	9.16	8.47	8.06	7.62
1973				9.28	8.50	7.59	7.80	9.06	8.36	7.96	7.52
1974				9.75	8.45	7.45	7.72	9.09	8.35	7.93	7.48
1975					7.96	7.04	7.50	9.03	9.26	7.84	7.39
1976					6.95	6.47	7.23	9.02	8.18	7.75	7.29
1977						6.24	7.30	9.33	8.32	7.82	7.31
1978						6.51	7.72	9.94	8.62	8.00	7.42
1980							8.27	11.50	9.04	8.14	7.41
1984									5.56	5.92	5.61
1988											5.05

[a]The costs are in 1972 U.S. Dollars.

Table D.5:

AVERAGE GOES COSTS FROM YEAR i TO YEAR j -- EL SALVADOR[a]
Secondary School Only
Interest Rate = 7.5%

	TO YEAR j										
FROM YEAR i	1968	1970	1972	1974	1976	1978	1980	1982	1984	1986	1988
1966		177.52	44.19	25.37	18.39	14.93	13.56	13.52	12.51	11.84	11.25
1969		70.79	24.48	16.28	12.96	11.04	10.47	10.92	10.25	9.81	9.40
1971			13.99	11.20	9.85	8.78	8.68	9.43	8.94	8.63	8.33
1972			11.25	9.84	8.98	8.10	8.15	9.03	8.57	8.29	8.01
1973				9.26	8.56	7.74	7.87	8.87	8.40	8.13	~.85
1974				9.75	8.52	7.58	7.78	8.89	8.38	8.09	7.80
1975					8.00	7.12	7.49	8.79	8.25	7.96	7.65
1976					6.95	6.48	7.16	8.73	8.14	7.84	7.52
1977						6.23	7.22	9.07	8.32	7.95	7.58
1978						6.51	7.68	9.78	8.72	8.22	7.77
1980							8.27	11.55	9.33	8.51	7.88
1984									5.56	5.92	5.64
1988											5.05

[a]The costs are in 1972 U.S. Dollars.

Table D.6:

AVERAGE GOES COSTS FROM YEAR i TO YEAR j -- EL SALVADOR[a]
Secondary School Only
Interest Rate = 15%

	TO YEAR j										
	1968	1970	1972	1974	1976	1978	1980	1982	1984	1986	1988
FROM YEAR i											
1966		193.56	50.47	29.83	22.15	18.41	16.81	16.45	15.55	14.96	14.50
1969		71.56	25.75	17.48	14.15	12.29	11.66	11.87	11.36	11.03	10.75
1971			14.10	11.39	10.13	9.16	9.02	9.55	9.21	9.01	8.83
1972			11.25	9.87	9.08	8.31	8.31	8.96	8.66	8.48	8.31
1973				9.24	8.62	7.87	7.96	8.73	8.42	8.25	8.08
1974				9.75	8.59	7.71	7.84	8.73	8.39	8.20	8.02
1975					8.04	7.19	7.49	8.57	8.21	8.01	7.82
1976					6.95	6.49	7.10	8.46	8.05	7.85	7.64
1977						6.22	7.14	8.83	8.27	8.01	7.75
1978						6.51	7.63	9.62	8.77	8.39	8.05
1980							8.27	11.58	9.59	8.85	8.32
1984									5.56	5.91	5.67
1988											5.05

[a]The costs are in 1972 U.S. Dollars.

Table D.7:

AVERAGE TOTAL COSTS FROM YEAR i TO YEAR j -- EL SALVADOR[a]
Elementary and Secondary School Coverage
Interest Rate = 0

	TO YEAR j										
	1968	1970	1972	1974	1976	1978	1980	1982	1984	1986	1988
FROM YEAR i											
1966	∞	235.63	74.79	29.41	13.24	8.30	5.75	4.58	3.93	3.45	3.09
1969		131.25	57.40	24.24	11.46	7.44	5.31	4.29	3.73	3.29	2.97
1971			42.63	18.66	9.38	6.41	4.77	3.95	3.48	3.10	2.82
1972			17.92	11.56	6.85	5.18	4.12	3.53	3.18	2.87	2.64
1973				10.21	6.21	4.84	3.94	3.41	3.09	2.81	2.58
1974				8.05	5.44	4.46	3.73	3.27	2.99	2.73	2.52
1975					4.74	4.09	3.52	3.13	2.89	2.65	2.45
1976					3.97	3.77	3.34	3.00	2.79	2.57	2.38
1977						3.70	3.26	2.93	2.73	2.52	2.34
1978						3.81	3.22	2.89	2.69	2.48	2.30
1980							2.62	2.54	2.44	2.67	2.13
1984									2.31	2.03	1.90
1988											1.99

[a]The costs are in 1972 U.S. Dollars.

Table D.8:

AVERAGE TOTAL COSTS FROM YEAR i TO YEAR j -- EL SALVADOR[a]
Elementary and Secondary School Coverage
Interest Rate = 7.5%

	TO YEAR j										
	1968	1970	1972	1974	1976	1978	1980	1982	1984	1986	1988
FROM YEAR i											
1966	∞	254.95	82.72	34.59	16.36	10.49	7.35	5.91	5.11	4.55	4.15
1969		134.63	60.50	27.14	13.46	8.93	6.45	5.28	4.62	4.15	3.80
1971			43.70	20.05	10.48	7.29	5.49	4.60	4.09	3.71	3.42
1972			17.92	11.79	7.18	5.50	4.44	3.86	3.51	3.23	3.01
1973				10.33	6.42	5.06	4.17	3.67	3.36	3.10	2.90
1974				8.05	5.53	4.57	3.88	3.46	3.19	2.96	2.78
1975					4.77	4.14	3.61	3.26	3.03	2.83	2.66
1976					3.97	3.77	3.38	3.09	2.89	2.70	2.55
1977						3.70	3.69	3.00	2.81	2.63	2.48
1978						3.81	3.25	2.95	2.76	2.58	2.44
1980							2.62	2.57	2.46	2.32	2.19
1984									2.31	2.05	1.92
1988											1.99

[a]The costs are in 1972 U.S. Dollars.

Table D.9:

AVERAGE TOTAL COSTS FROM YEAR i TO YEAR j -- EL SALVADOR[a]
Elementary and Secondary School Coverage
Interest Rate = 15%

	TO YEAR j										
FROM YEAR i	1968	1970	1972	1974	1976	1978	1980	1982	1984	1986	1988
1966	∞	275.36	91.47	40.67	20.33	13.49	9.72	7.98	7.02	6.40	5.96
1969		137.95	62.62	30.28	15.83	10.84	8.02	6.69	5.96	5.46	5.12
1971			44.72	21.47	11.70	8.34	6.40	5.46	4.93	4.55	4.29
1972			17.92	12.02	7.53	5.86	4.81	4.25	3.91	3.67	3.48
1973				10.44	6.62	5.29	4.43	3.95	3.66	3.44	3.28
1974				8.05	5.61	4.69	4.04	3.65	3.41	3.22	3.07
1975					4.80	4.19	3.69	3.38	3.18	3.01	2.88
1976					3.97	3.78	3.42	3.16	2.99	2.84	2.72
1977						3.69	3.32	3.06	2.89	2.74	2.63
1978						3.81	3.28	3.01	2.83	2.68	2.56
1980							2.62	2.59	2.49	2.36	2.26
1984									2.31	2.06	1.94
1988											1.99

[a]The costs are in 1972 U.S. Dollars.

Table D.10:

AVERAGE GOES COSTS FROM YEAR i TO YEAR j -- EL SALVADOR[a]
Elementary and Secondary School Coverage
Interest Rate = 0

	TO YEAR j										
	1968	1970	1972	1974	1976	1978	1980	1982	1984	1986	1988
FROM YEAR i											
1966		162.50	38.65	17.67	9.20	6.35	4.75	3.95	3.50	3.13	2.84
1969		70.00	23.23	13.09	7.62	5.59	4.36	3.70	3.32	2.99	2.73
1971			13.88	10.12	6.53	5.05	4.08	3.52	3.19	2.89	2.65
1972			11.25	9.23	6.13	4.84	3.96	3.44	3.13	2.84	2.62
1973				8.80	5.83	4.67	3.86	3.38	3.08	2.81	2.59
1974				8.05	5.44	4.46	3.74	3.30	3.02	2.76	2.55
1975					4.74	4.09	3.58	3.16	2.92	2.68	2.48
1976					3.97	3.77	3.35	3.03	2.82	2.60	2.42
1977						3.70	3.28	2.96	2.76	2.55	2.37
1978						3.81	3.24	2.92	2.72	2.51	2.34
1980							2.67	2.58	2.48	2.31	2.16
1984									2.34	2.07	1.94
1988											2.02

[a]The costs are in 1972 U.S. Dollars.

Table D.11:

AVERAGE GOES COSTS FROM YEAR i TO YEAR j -- EL SALVADOR[a]
Elementary and Secondary School Coverage
Interest Rate = 7.5%

	TO YEAR j										
	1968	1970	1972	1974	1976	1978	1980	1982	1984	1986	1988
FROM YEAR i											
1966		177.52	44.19	20.69	10.96	7.59	5.68	4.75	4.22	3.82	3.53
1969		70.79	24.48	14.08	8.39	6.21	4.88	4.19	3.78	3.46	3.22
1971			13.99	10.34	6.85	5.37	4.39	3.84	3.51	3.24	3.02
1972			11.25	9.31	6.33	5.06	4.20	3.71	3.40	3.14	2.95
1973				8.84	5.98	4.84	4.06	3.60	3.32	3.07	2.88
1974				8.05	5.53	4.57	3.89	3.48	3.22	2.99	2.81
1975					4.77	4.14	3.62	3.28	3.06	2.85	2.69
1976					3.97	3.77	3.39	3.11	2.92	2.73	2.58
1977						3.70	3.31	3.03	2.84	2.66	2.51
1978						3.81	2.67	2.98	2.79	2.61	2.48
1980							2.67	2.61	2.50	2.36	2.23
1984									2.34	2.08	1.95
1988											2.02

[a]The costs are in 1972 U.S. Dollars.

Table D.12:

AVERAGE GOES COSTS FROM YEAR i TO YEAR j -- EL SALVADOR[a]
Elementary and Secondary School Coverage
Interest Rate = 15%

FROM YEAR i	TO YEAR j 1968	1970	1972	1974	1976	1978	1980	1982	1984	1986	1988
1966	∞	193.56	50.47	24.40	13.29	9.34	7.07	5.99	5.37	4.96	4.67
1969		71.56	25.75	15.17	9.29	6.99	5.57	4.85	4.43	4.13	3.91
1971			14.10	10.56	7.18	5.72	4.75	4.22	3.90	3.66	3.49
1972			11.25	9.38	6.53	5.30	4.47	4.00	3.72	3.50	3.33
1973				8.88	6.12	5.02	4.27	3.84	3.58	3.37	3.22
1974				8.05	5.61	4.69	4.05	3.67	3.43	3.24	3.10
1975					4.80	4.19	3.70	3.40	3.20	3.03	2.90
1976					3.97	3.78	3.43	3.18	3.01	2.86	2.74
1977						3.69	3.33	3.09	2.92	2.77	2.65
1978						3.81	3.29	3.03	2.86	2.71	2.59
1980							2.67	2.63	2.53	2.40	2.30
1984									2.34	2.10	1.97
1988											2.02

[a]The costs are in 1972 U.S. Dollars.

APPENDIX E: SUPPLEMENTARY TABLES FOR THE IVORY COAST

Tables E.1 to E.3 on the following pages show the values of

Insert Tables E.1 to E.3 about here

AC_{ij} for the Ivory Coast elementary school television system. Table E.1 uses a social discount rate of 0; Table E.2 uses 7.5%; and Table E.3 uses 15%. Section II.C of the text describes the definition of the AC_{ij} terms and Section III.B discusses the Ivory Coast data further.

Table E.1:

AVERAGE COSTS FROM YEAR I TO YEAR J -- IVORY COAST[a]
Elementary School Coverage
Interest Rate = 0

	TO YEAR J										
FROM YEAR I	1970	1972	1974	1976	1978	1980	1982	1984	1986	1988	1990
1969	∞	116.53	41.13	22.87	15.69	12.45	10.73	9.45	8.75	8.24	7.78
1971		61.94	29.55	18.57	13.50	11.08	9.75	8.70	8.15	7.74	7.36
1972		45.00	24.72	16.60	12.44	10.41	9.27	8.32	7.84	7.49	7.14
1973			20.82	14.86	11.47	9.77	8.80	7.95	7.54	7.24	6.93
1974			18.13	13.44	10.60	9.19	8.36	7.60	7.26	7.00	6.73
1975				12.09	9.75	8.61	7.92	7.25	6.97	6.76	6.52
1976				10.72	8.89	8.03	7.49	6.89	6.68	6.52	6.31
1977					8.21	7.58	7.15	6.60	6.44	6.32	6.14
1978					7.55	7.22	6.88	6.36	6.25	6.16	5.99
1980						7.09	6.63	6.04	5.99	5.95	5.81
1984								5.65	5.82	5.82	5.65
1988										5.83	5.46
1990											5.50

[a]The costs are in 1972 U.S. Dollars.

Table E.2:

AVERAGE COSTS FROM YEAR I TO YEAR J -- IVORY COAST[a]
Elementary School Coverage
Interest Rate = 7.5%

	TO YEAR J										
FROM YEAR I	1970	1972	1974	1976	1978	1980	1982	1984	1986	1988	1990
1969	∞	126.54	45.86	26.04	18.26	14.70	12.83	11.51	10.75	10.20	9.74
1971		62.83	30.83	19.85	14.78	12.32	10.99	9.99	9.43	9.03	8.68
1972		45.00	25.22	17.30	13.27	11.28	10.17	9.31	8.84	8.50	8.20
1973			20.95	15.22	11.99	10.36	9.44	8.70	8.31	8.02	7.76
1974			18.13	13.60	10.91	9.58	8.81	8.15	7.83	7.60	7.37
1975				12.15	9.92	8.84	8.22	7.64	7.38	7.19	6.99
1976				10.72	8.96	8.15	7.66	7.15	6.95	6.81	6.65
1977					8.23	7.63	7.24	6.77	6.62	6.51	6.37
1978					7.55	7.23	6.92	6.47	6.36	6.28	6.16
1980						7.09	6.65	6.10	6.05	6.01	5.90
1984								5.65	5.82	5.81	5.67
1988										5.83	5.46
1990											5.50

[a]The costs are in 1972 U.S. Dollars.

Table E.3:

AVERAGE COSTS FROM YEAR I TO YEAR J -- IVORY COAST[a]
Elementary School Coverage
Interest Rate = 15%

	TO YEAR J										
	1970	1972	1974	1976	1978	1980	1982	1984	1986	1988	1990
FROM YEAR I											
1969	∞	137.28	51.26	29.86	21.48	17.64	15.67	14.37	13.61	13.08	12.68
1971		63.68	32.13	21.22	16.19	13.76	12.47	11.57	11.06	10.70	10.42
1972		45.00	25.70	18.02	14.15	12.23	11.20	10.44	10.03	9.74	9.51
1973			21.06	15.56	12.51	10.98	10.14	9.50	9.17	8.93	8.74
1974			18.13	13.76	11.22	9.97	9.28	8.73	8.45	8.26	8.10
1975				12.21	10.09	9.08	8.52	8.03	7.81	7.66	7.52
1976				10.72	9.03	8.27	7.83	7.40	7.23	7.11	6.99
1977					8.26	7.68	7.33	6.94	6.81	6.71	6.61
1978					7.55	7.24	6.96	6.57	6.47	6.41	6.32
1980						7.09	6.67	6.17	6.11	6.07	5.98
1984								5.65	5.81	5.81	5.69
1988										5.83	5.47
1990											5.50

[a]The costs are in 1972 U.S. Dollars.

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