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24

Cost factors in planning educational technology systems

Dean T. Jamison

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Paris 1977
Unesco: International Institute for Educational Planning

The Swedish International Development Authority (SIDA)
has provided financial assistance for the publication of this booklet

Published in 1977 by the United Nations
Educational, Scientific and Cultural Organization,
7 Place de Fontenoy, 75700 Paris
Printed by NICI, Ghent
Cover design by Bruno Pfäffli

ISBN 92-803-1076-3

Fundamentals of educational planning

The booklets in this series are written primarily for two types of clientèle: those engaged in—or preparing for—educational planning and administration, especially in developing countries; and others, less specialized, such as senior government officials and policy-makers who seek a more general understanding of educational planning and of how it is related to overall national development. They are devised to be of use either for private study or in formal training programmes.

Since this series was launched in 1967 the practice as well as the concept of educational planning has undergone substantial change. Many of the assumptions which underlay earlier attempts to put some rationality into the process of educational development have been abandoned or at the very least criticized. At the same time, the scope of educational planning itself has been broadened. In addition to the formal system of schools, it now includes other important educational efforts in non-formal settings and among adults. Attention to the growth and expansion of educational systems is being supplemented and sometimes even replaced by a growing concern for the distribution of educational opportunities and benefits across different regions and across social, ethnic and sex groups. The planning, implementation and evaluation of innovations and reforms in the content and substance of education is becoming at least as important a preoccupation of educational planners and administrators as the forecasting of the size of the educational system and its output. Moreover, the planning process itself is changing, giving more attention to the implementation and evaluation of plans as well as to their design, and exploring such possibilities as integrated planning, participatory planning, and micro-planning.

One of the purposes of these booklets is to reflect this diversity by giving different authors, coming from a wide range of backgrounds and disciplines, the opportunity to express their ideas and to communicate their experience on various aspects of changing theories and practices in educational planning.

Although the series has been carefully planned, no attempt has been made to avoid differences or even contradictions in the views expressed by the authors. The Institute itself does not wish to impose any official doctrine on any planner. Thus, while the views are the responsibility of the authors and may not always be shared by Unesco or the IIEP, they are believed to warrant attention in the international forum of ideas.

Since readers will vary so widely in their backgrounds, the authors have been given the difficult task of introducing their subjects from the beginning, explaining technical terms that may be commonplace to some but a mystery to others, and yet adhering to scholarly standards. This approach will have the advantage, we hope, of making the booklets optimally useful to every reader.

Preface

Over the past fifteen years or more we have witnessed an increase in the number of experiments in the use of instructional radio and television and a rapid growth of research on this subject. A wealth of experience has been accumulated in this area and it seemed to us that some form of progress report was called for, particularly in order to define the current cost of using these media.

Jamison begins by reminding us of the reasons why the use of these communications techniques raised such high hopes: first of all, it was reckoned that their use on a sufficiently broad scale would improve cost effectiveness *vis-à-vis* the traditional methods of teaching (by reducing costs and/or improving the effectiveness of the instruction); in addition, it was seen as a means for extending education to groups of children or adults which were not easily accessible to the traditional school system (e.g. small or remote rural communities; working men and women etc.).

The author goes on to study the data available on costs, and the great merit of this analysis lies in the fact that it covers experience in a wide range of countries and the findings are presented in a compatible form. It is thus possible to make valid comparisons and in particular observe that the costs per student/hour vary substantially in relation to the size of the audience and the way the project is planned and set up. Jamison follows this with some vital facts on the cost functions for each activity in a project, i.e. central administration and start-up costs; programme production costs; transmission costs; and reception costs. Such information will doubtless enable those responsible for such projects to have a better idea of the options available at each stage and plan any future system on a more effective cost basis.

The section which discusses the effectiveness of instructional radio and television is less detailed and this is chiefly due to the conceptual and methodological difficulties involved in comparing different methods of instruction and the relatively limited number of case studies so far available in this area. Different methods of instruction are generally aimed at achieving different objectives and there must therefore be agreement on what one wants to compare, i.e. should this comparison be restricted to cognitive objectives or extended to include emotional objectives? How is one to decide priorities between the various objectives? How should a valid comparison be made (i.e. where the effect of all the other factors can be eliminated) and how can one devise the ways and means for doing this? These are the challenging questions facing researchers in this area. But none the less the studies carried out so far would seem to indicate that it is possible, using the current methods of instructional television, to achieve effectiveness comparable to that of traditional teaching.

This analysis of the situation will certainly prove an extremely useful tool for all those—administrators, planners and researchers—who in their work are, or will be, required to concern themselves with the use of modern communications media in the field of education.

Hans N. Weiler
Director, IIEP

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Acknowledgments

This monograph is based in part on *Cost analysis for educational planning and evaluation: methodology and application to instructional technology,* which I wrote with Steven J. Klees and Stuart J. Wells, and which will be published by Sage Publications in the autumn of 1977. I wish to acknowledge the strong intellectual debt I have to Klees and Wells for their contributions to our collaborative work in this area. I also wish to acknowledge financial support I have received from the U.S. Agency for International Development and from the U.S. National Science Foundation; without their support, undertaking this research would have been impossible. Finally, Unesco's International Institute for Educational Planning made its facilities available to me during the writing of part of the manuscript, and I benefitted from related ongoing studies of Unesco's Division of Educational Methods, Materials, and Techniques. The conclusions and opinions expressed herein do not necessarily reflect the official views of the International Bank for Reconstruction and Development or of any of the sources of support.

I. Introduction

The educational systems of low-income countries throughout the world share many or all of the following familiar problems: (i) they have rising costs, (ii) they provide relatively poor access for rural children, (iii) they provide a low quality of instruction, which often results in children from low-income countries acquiring less cognitive knowledge than do children from high-income countries, (iv) they exhibit slow response in providing education relevant to development goals, and (v) their impact on income distribution is adverse because children from high-income families tend to receive a disproportionate share of educational opportunities. In response to these problems a range of responses for educational policy has been proposed. Some have argued that the problems are so important and intractable that the best course is simply to cut back on educational expenditures to the extent feasible politically. Others have argued for a vast expansion of 'nonformal' education—outside existing educational establishments—in order to alleviate the problems listed. Still others argue that reform within educational systems can respond, at least in part, to these problems. My purpose in this monograph is not to discuss the relative merits of these broad approaches, but rather, within the context of the reform approach, to examine the economic potential instructional technologies have for improving formal education.

An expanding international experience with the use of instructional radio and television has led an increasing number of reform advocates to consider seriously the expanded use of these technologies to reduce costs, to improve the quality, or to improve access to education. Previously heard claims that the new media would quickly and dramatically influence educational practice seem, in retrospect, far off the mark; none the less, there has been an ever-growing number of successful uses of instructional technology, and these successes suggest the importance of increasingly careful consideration of technology in planning the future growth of educational systems. This monograph is designed to assist planners considering the use of technologies by providing information about economic factors bearing on their use.[1]

In Section II I review aspects of the literature dealing with the effectiveness of instructional technology, and, in Sections III and IV, I turn to the principal focus of the monograph, the economic and cost factors associated with technology's use. Section III discusses factors involved in planning system costs and summarizes prior cost experiences. Section IV provides information for planning future system costs. A concluding section draws conclusions for policy. Two appendixes treat specific topics in more detail: Appendix A presents additional information on the methodology of costing educational media systems, and Appendix B discusses cost trade-offs.

1. This monograph addresses the needs of planners in low-income countries and hence contains no discussion of computer-assisted and computer-managed instruction because of their high cost. Thus the term 'instructional technology' herein simply denotes instructional radio and television with, again for cost reasons, an emphasis on radio. More detailed descriptive information on radio's use for both formal and nonformal education in low-income countries appears in the case studies edited by Spain, Jamison, and McAnany (1977); Jamison and McAnany (1977) provide an overview of those radio case studies and related literature.

II. Uses of instructional radio and television

Uses for instructional technologies fall naturally into three broad categories: improving educational quality and relevance; lowering educational costs (or the rate of increase of costs); and improving access to education, particularly in rural areas. In this section I discuss very briefly reasons to believe that increased use of technology has the *potential* to improve education in each of these three ways.

A. Quality improvement

Early developers of educational technology were perhaps most strongly motivated by the potential they believed to exist for educational technology to improve quality. Early results almost uniformly disappointed those who held this belief. Reports of research on the instructional effectiveness of the media tended overwhelmingly to conclude that there were 'no significant differences' between, for example, student performance in a class taught by an instructor on the one hand or, on the other hand, by that same instructor on television or audio-tape. A number of comprehensive surveys exist (Chu and Schramm, 1967; Jamison, Suppes and Wells, 1974; Schramm, 1976) on this point, and we quote the conclusions of Jamison, Suppes and Wells (1974, p. 56) here:

> "Though there is a substantial past history in the use of instructional radio, few studies of its effectiveness exist. A number that do exist were, however, carefully done and they indicate that instructional radio, supplemented with appropriate printed material, is about as effective as traditional instruction. Despite this potential, the extent to which

instructional radio can be substituted for traditional instruction remains to be tested. There is a much more extensive research literature on the effectiveness of instructional television, and excellent surveys of that literature already exist. There is strong evidence that instructional television, used in a way that closely simulates traditional instruction, is as effective, on the average, as traditional instruction for all grade levels and subject matters. There is very little evidence concerning the effectiveness of instructional television used in ways that utilize the unique capabilities of the medium. A number of students and teachers have an initially unfavorable attitude toward instructional television, although the incidence of unfavorable attitudes tends to diminish as institutions gain experience with the medium. After such experience a majority of students have neutral or favorable attitudes toward instructional television."

While these findings of equal effectiveness disappointed those hoping for dramatic breakthroughs in instructional technique, they none the less have two important policy implications. First, as will be discussed in the next section, the finding of equal effectiveness leaves open the possibility of reducing costs, which may be particularly important if there is a substantial unmet social demand for education. Second, because the media are effective, their availability makes possible the provision of instruction in curriculum areas deemed important, but in which existing teachers are untrained. Perhaps the most dramatic such use is in language instruction; examples of this include using radio to teach English in Thailand, the Philippines, and the Peoples Republic of China, and using television to teach French in the Ivory Coast. Other curriculum areas in which existing teachers may be untrained include natural science and mathematics, agricultural practices, and hygiene and public health. Thus even though the media in many cases do no better than a competent teacher, there may none the less be valuable rôles for them to play.

Despite the general finding of no significant difference, there are, nevertheless, occasional examples in which the media have outperformed traditional instructional practices. A number of these examples come from low-income countries where, presumably because of the poor quality of traditional instruction, achievement test scores tend to lag far behind those of high-income countries. Three well-documented examples in which technology is improving quality are in El Salvador, Mexico, and Nicaragua. El Salvador makes heavy use of television in grades 7-9; an extensive evaluation of that project (Mayo, Hornik and McAnany, 1976) found students using TV to be learning somewhat more than those having no access to it. The Mexican *Telesecundaria* provides beginning-level secondary instruction to students in rural areas near Mexico City; the *Telesecundaria* may be of principal interest because it provided access to school for hitherto excluded rural groups, but evaluation of it (Mayo, McAnany and Klees, 1975; Klees, 1975) also suggested that television improved students' test scores. Perhaps the most promising application of technology to improve quality is in Nicaragua's Radio Mathematics Project. In that project radio carries the principal burden of instruction in mathematics for early-elementary school pupils. Great effort is put into programming the radio lessons to maximize the children's interest and involvement, and in the course of each of the daily 30-minute radio broadcasts, each child is required to make upward of 40 active responses to questions posed in the radio broadcast. A comprehensive evaluation of the project (Searle, Matthews, Suppes and Friend, 1977) found achievement gains from radio instruction over traditional instruction that were highly significant both statistically and educationally. A separate evaluation of the project's impact on student repetition rates (Jamison, 1977) found radio to reduce repetition by an amount that generated cost savings (from avoiding the re-enrolment of repeaters) far in excess of radio's costs.

Part of the reason that so many comparisons of media with traditional instruction found equal effectiveness appears to result from the notions of scientific adequacy held by the researchers—notions that an outsider can only find perplexing. To be scientifically adequate, these researchers seemed to feel, a comparison of television with traditional instruction, say, should hold everything constant except the medium: one should have the same lecturer (on TV and off), lecturing in the same way to the same sorts of pupils in the same environment. The results tended to be no difference in outcome. As an increasing number of projects begin (as the Nicaraguan project already has) to explore fully the potential of the media, I would predict an increasing number of findings of quality improvement.

B. Cost reduction

As the principal focus of this monograph is on the costs of the media, I will be relatively brief at this point in discussing cost reduction as an objective of media use. An argument that, in the long term, media will be increasingly used to help keep costs down results from the rising real costs of traditional instruction. Historical experience over the last two decades has shown rapidly rising educational system costs for both developing and developed nations. One reason for the observed increasing expenditures on education has been large enrolment expansion, especially in developing countries. However, also of great importance is that, over time, it is becoming more expensive to educate each child in the system.

The increasing costs of educating a pupil do not appear to be the result of increases in the quality of education offered. On the contrary, it is probable that the quality of educational output is at best remaining constant, or perhaps even declining (see Woodhall and Blaug, 1968). The most plausible explanation of the increasing costs per student was formalized by Baumol (1967) and stated simply by Coombs (1968, p. 7): "Education's technology, by and large, has made surprisingly little progress beyond the handicraft stage." Essentially, the point is that although the educational process has made little, if any, gains in productivity, most other sectors of the economy have. Relatively progressive industries, using the more advanced technologies, partially determine the salary levels that the less progressive industries will have to pay to attract competent people. Therefore, in general, educational systems have had to pay more over time for the same quality teacher. It has been the hope that innovations in instructional technology can aid the education sector in increasing its productivity, together with the more progressive sectors of the economy. Relatively little of the potential of such technologies has yet been realized. However, it is likely that the near future will bring increased traditional educational system costs (through rising real teacher costs) relative to instructional technology system costs (through reduction in or maintenance of the real costs of various technological alternatives), and thus the pressures to introduce these latter, more capital-intensive, techniques will be increased.

In the shorter term, the potential for use of technology to reduce costs per pupil per year is probably strongest at the secondary and post-secondary levels. At those levels the use of radio (and perhaps television) with correspondence for 'distance learning' has demonstrated a capacity to reduce costs dramatically. The Open University of the United Kingdom is perhaps the best known distance learning system, but others are in operation in Botswana, the Dominican Republic, France, Germany, Japan, Kenya, Mauritius, and elsewhere (Schramm, 1976; MacKenzie, Postgate and Scupham, 1975). Distance learning systems realize their substantial cost advantages by requiring that students meet with teachers only occasionally—for two weeks in the summer, say, or at a monthly tutorial meeting.

C. Improving access

A final potential use for instructional technologies is improving access to schooling for rural or urban disadvantaged groups. There are two broad approaches through which technology has been used in this way—distance learning and what might be labelled 'extended schools'.

The first, distance learning, was mentioned above as being much less costly than more traditional forms of secondary and post-secondary instruction. Simply because of its lower cost, distance learning can improve access because, for any given budget level, more individuals can be reached with a distance learning system than with a traditional one. Perhaps more important in terms of access, though, is that distance learning systems can dissolve barriers both of distance and of time to access to schooling. Traditionally, schools at higher levels exist principally in population centres because large total numbers of students are required to make such schools economically viable. This results in students from rural areas either being denied secondary schooling or having to bear large travel or subsistence costs. This is far less of a problem with distance learning systems. Since traditional schools typically meet at fixed hours during the day, finding time to attend is frequently a problem for the poor who must work during the day to maintain their incomes. Distance study allows shifting the time for learning to the evening, aiding thereby a poor student's problem of financing continued education. These points reflect the attractive side of distance learning systems; important problems—of organization, programme preparation, management, accreditation, and political acceptance—none the less remain. In those cases where these problems have been overcome, distance learning has achieved marked success.

A second way in which technologies have been used to improve access is through allowing the creation of relatively small but nevertheless self-sufficient schools in rural areas. An excellent example of this is the Mexican *Telesecundaria,* which was mentioned earlier. A number of rural towns in the provinces surrounding Mexico City equipped churches, community centres, or other unused space with a television receiver and benches; the Ministry of Education provided these schools with a poorly trained primary teacher and broadcast courses for the TV sets. Through receiving the bulk of their instruction by television, tens of thousands of pupils completed the first cycle of secondary school at relatively low cost and with relatively high achievement (Mayo, McAnany, and Klees, 1975). Oliviera (1977) describes a similar use of television in Brazil, and Spain (1973) describes a more limited effort using radio for this purpose. This is a more costly approach to extending access than is distance learning, but closer in structure to traditional schooling. There is by now enough experience with extending schooling in this way that it is an option for serious consideration by educational planners.

III. Cost functions for instructional technology

My purpose in this section is to describe the basic concepts of economic analysis that are required for understanding the cost behaviour of educational technology systems. Jamison, Klees and Wells (1976) recently completed an extensive monograph on educational technology costs, and I draw on that work here; other discussions of educational technology costs appear in Schramm, Coombs, Kahnert, and Lyle (1967), General Learning Corporation (1968), Carnoy (1975) and Carnoy and Levin (1975). Perhaps the best overall reference on educational system costs is an IIEP volume by Coombs and Hallak (1972).

This section begins by discussing the concept of a cost function and the related concepts of total, average, and marginal cost. To a first approximation cost functions for educational technology fit into a convenient form that separates 'fixed' and 'variable' costs, and I next discuss that case. Capital costs for educational technology are high, and for that reason it is important that planners deal with them properly; I touch on these matters here and deal with them more explicitly in Appendix A. The final part of this section presents actual cost functions for a number of ongoing systems in order to give a feel for the methods employed and the costs to be expected. The next section then examines in much more detail the costs of the various components of educational radio and television systems.

A. Total, average and marginal cost

It is useful to think of costs as functions rather than as 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. Total cost will, of course, increase as N increases.

The *average cost function* (or, equivalently, *unit cost function*) is defined to equal the total 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. Typically, however, for educational technology systems, average costs will *decrease* as N increases.

The *marginal cost function* 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 given by:

$$\text{Marginal cost} = MC(N) = TC(N+1) - TC(N).$$

That is, the marginal cost at any given level of student utilization, N, is equal to the total cost for N + 1 students minus the total cost for N students. It is often feasible to assume that the marginal cost of adding one more student to a system is constant, that is, it is independent of the number of students already served.

To illustrate the concepts above let us construct a simple arithmetic example. In Table 1 the first column indicates the number of

TABLE 1. Total, average, and marginal cost example

Unit (students) N	Total Cost TC(N)	Average Cost AC(N)	Marginal Cost MC(N)
0	$ 0	$ 0	
1	30	30	30
2	70	35	40
3	105	35	35
4	120	30	15
5	130	26	10

SOURCE Jamison, Klees and Wells (1967)

students served by a particular educational programme, while the second column indicates the total costs of serving that number of students. We see that the example has been constructed to indicate that total costs are some function of the number of students; that is, total costs increase as the number of students increases. From the information presented in the first and second columns we can derive the average and marginal cost information presented in the third and fourth columns. The average cost is simply the total cost divided by the number of students while the marginal cost is the addition to total costs caused by the addition of one more student to the system. The average cost measured is most useful as an historical summary of the system's efficiency in doing its task, while the marginal cost measure is more useful for examining the cost consequences of expanding or contracting the system, in terms of the number of students served.[1]

B. Fixed and variable costs

When the total cost function can be approximated by the simple and convenient linear form

$$TC(N) = F + VN,$$

it becomes possible to separate costs into fixed costs and variable costs. In this example, F would be the *fixed cost* because the value of cost contributed by the first term on the right-hand side is independent of N; V is the *variable cost* 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 the average cost is simply equal to the fixed cost divided by

1. The example above also illustrates the relationship between average costs and marginal costs. For the average cost to rise as the system expands the marginal cost of adding another student must be greater than the average cost; for example, in expanding from serving one student to serving two students the marginal cost is $40, which is greater than the $30 average cost of serving one student—therefore, when the system expands to two students the average cost rises (from $30 to $35 in this case). Similarly, if the marginal cost is below the average cost, the average cost will fall as the system expands; this is illustrated in our example as the system expands to serve more than three students. When average and marginal costs are equal, expansion will yield the same average cost; this is illustrated above in the increase from two students to three students where the marginal cost of the increase is $35, which is the same as the average cost for two students, yielding a similar $35 average cost for three students.

N plus the variable cost ($AC(N) = \frac{F}{N} + V$); 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.

The above equation is a reasonable approximation to the cost behaviour of instructional technology systems.[1] Programme 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.

C. Capital and recurrent costs

A *capital cost* is one that is incurred to acquire goods or services 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; 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 their 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 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 they provide a valuable practical discussion of how to examine school building and facilities costs.

An occasional source of confusion, even among economists, is between fixed costs and capital costs. There can be fixed costs that

1. It should be emphasized that this linear formulation of the total cost function is in many cases only a rough approximation. For example, as the system expands to cover students from more heterogeneous cultures, more geographically distant locations, or less densely populated areas, both the variable cost per student and the marginal cost per student may not remain constant (and will not necessarily be equal either), but may increase.

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, thought it is often true that major capital expenditures are associated with substantial fixed costs.

How does one construct the cost functions discussed in the preceding section if capital costs are present? Let us say that a school system buys a radio transmitter and 6,000 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 the use of radio in year 1; likewise it would be inappropriate, in computing year-3 costs, to consider the use of transmitter and receivers as free. In order to construct a useful cost function it is necessary to *annualize* the expenditure on capital equipment.

In annualizing a capital cost one must take account both of how long the capital equipment will last and the interest rate one could receive on the capital if it were invested in bonds, say, instead of in the transmitter and receivers. The resulting annualization can reasonably be thought of as the rent one would have to pay if the equipment were leased rather than purchased. To continue with the example of the preceding paragraph, if the $220,000 worth of equipment had an expected lifetime of 10 years, and if the interest rate were 7.5 per cent per year, the annualized cost (rental value) of the equipment would be $32,051 per year. Appendix A discusses methods for handling capital costs in more detail.

D. Cost functions for actual projects

This subsection consists principally of three tables that give cost functions for a number of projects that are either operational now or should become so soon. Table 2 gives cost summaries for four instructional radio projects. The Radio Mathematics Project in Nicaragua and the Thai project have improving instructional quality as their principal objectives; the two Mexican projects are oriented to improving access to schooling by using radio to bring parts of the elementary school curriculum to where it would otherwise be unable to reach.

Table 3 gives cost summaries of four instructional television projects. The El Salvador project (described in detail in Mayo,

TABLE 2. Cost summary of four instructional radio projects[1]

Project	Year of information source	N	h	F	V	AC(N)	Cost per student/hour
Nicaragua[2]	1975	250 000	450	251 000	3.83	4.84	0.064
Mexico-Radioprimaria	1972	2 800	280	45 600	0.19	16.44	0.068
Mexico Tarahumara	1972	1 081	640	56 300	0.50	52.86	0.331
Thailand[3]	1967	800 000	165	125 800	0.28	0.44	0.018

1. Values in this table were computed with an interest rate of 7.5 per cent; all values are in 1975 US dollars. The symbols are defined as follows: N = number of students using project (in the given year, unless otherwise noted); h = the number of hours of programming broadcast per year; F = annualized fixed costs; V = annualized variable cost per student; AC(N) = average annual cost per student for the given value of N; and the student/hour cost is the annual cost per student-hour of viewing for the given values of N and h.
2. The values of N and h chosen for the IR project in Nicaragua reflect *potential* utilization of the system as discussed in the case study in Chapter V of Jamison, Klees and Wells (1976). The high variable cost, V, reported in this table for Nicaragua has subsequently been reduced to about $1.75 (Searle, Friend and Suppes, 1976, p. 29).
3. See Schramm, Coombs, Kahnert and Lyle (1967) for a description of the Thai instructional radio project and for the cost data upon which this cost function is based.

SOURCE Jamison, Klees and Wells (1976)

TABLE 3. Cost summary of four instructional television projects[1]

Project	Year of information source	N	h	F	V	AC(N)	Cost per student/hour
El Salvador	1972						
Total Costs		48 000	540	1 395 000	1.38	30.44	0.179
GOES Costs		48 000	540	999 000	1.38	22.19	0.130
Hagerstown	1973	22 000	1 440	1 467 000	0.81	67.79	0.575
Korea[2]	1976	1 000 000	560	1 757 000	2.26	4.03	0.056
Mexico	1972	29 000	1 080	726 300	5.31	30.34	0.084

1. Values in this table were computed with an interest rate of 7.5 per cent; all values are in 1975 US dollars. The symbols are defined as follows; N = number of students using project (in the given year, unless otherwise noted); h = the number of hours of programming broadcast per year; F = annualized fixed costs; V = annualized variable cost per student; AC(N) = average annual cost per student for the given value of N; and the student/hour cost is the annual cost per student hour of viewing for the given values of N and h.
2. The N and h for Korea reflect planned utilization of the system as discussed in Jamison and Kim (1977). Though studio facilities are now complete, and pilot testing of programmes is under way, the Korean ETC System remains to become operational.

SOURCE Jamison, Klees and Wells (1976)

Hornik and McAnany, 1976) attempted both to reduce costs and to improve quality; the Hagerstown, U.S.A., and Korea projects emphasize quality improvement; and the Mexican *Telesecundaria* Project emphasizes improved access to schooling in rural area. Table 3 shows two cost functions for El Salvador—one that reflects all costs and another that reflects only costs to the Government of El Salvador (GOES). GOES costs differ substantially from total costs because of the substantial external aid provided to the project; Jamison and Klees (1975) discuss in more detail the implications of external aid for cost analysis of the El Salvador and other projects.

Table 4 gives cost functions for three distance learning projects that used radio combined with text and workbooks to improve access to schooling. Cost data for these projects are scantier than for the in-school projects whose costs appear in Tables 2 and 3; the cost functions for the distance learning projects should thus be regarded as less reliable than the others.

In examining the cost figures in these three tables several points should be kept in mind. First, the cost function for any given project is given by $TC(N) = F + VN$, where F and V are the appropriate table entries and include both recurrent and (annualized) capital costs. Thus, for example, the cost function of the Nicaragua project is given by $TC(N) = \$251{,}000 + \$3.83\ N$, where the costs are expressed in dollars per year. Thus if 250,000 students are enrolled the total cost per year will be $\$251{,}000 + (\$3.83 \times 250{,}000) = \$1{,}208{,}500$. (It should be noted that, in projecting to so large a number of students, the cost equation can change somewhat. Thus an equation such as this one, that is based on a relatively small number of students, should be regarded as only a first approximation).

Second, the average cost for any given value of N, AC(N), is simply the total cost for that value of N divided by N. For the Nicaragua project AC(250,000) is, then $\frac{\$1{,}208{,}000}{250{,}000} = \$4.84$, as table 1 indicates. Clearly as N gets larger AC(N) will decline, and much of the variation in AC(N) across projects results from variation in N rather than in the cost function. The values for AC(N) in the table should be compared with one another with some care both because of the differing objectives of the projects and because

TABLE 4. Cost functions for three distance learning projects[1]

Country	Source(s)	Nature of project	Cost function (dollars per year)	N	AC(N)
Kenya	Krival (1970) Schramm (1976)	in-service certification and upgrading of primary school backers	TC(N) = \$250 000 + 9.77N	10 100	\$34.50
Korea	Jamison and Kim (1976)	radio-correspondence high-school covering three grade levels	TC(N) = \$168 000 + 25 N[2]	30 000	\$30.60
Dominican	White (1976)	primary school equivalency for adults using radio, workbooks, and weekly meetings	TC(N) = \$152 000 + 8.7 N[3]	20 000	\$16.30

1. These cost functions are expressed in terms of 1975 dollars, with capital costs annualized at a 7.5 per cent interest rate; N is the approximate annual enrolment in the system; and AC(N) is the average cost per student per year, using the enrolment level given.
2. The high marginal cost for the Korea system results from its heavy reliance on textbooks; of the marginal cost of \$25, \$21 is for texts.
3. This cost function was constructed as an approximation to cost data given in White (1976, Section VIII).

the given values of N are sometimes actual and sometimes only planned. Third, one should keep in mind that both F and V can depend on many things (as discussed in Section IV); important among them is the number of hours of programming broadcast per year, h, which is shown in tables 2 and 3 and is itself the product of the number of grade levels covered and the average number of hours per year of media instruction received by each child. Fourth, the final column of tables 2 and 3 shows costs per student per hour; this is simply AC(N), the cost per student per year, divided by the number of hours per year that a student receives media instruction.

Tables 2, 3 and 4 all illustrate the cost-function approach to the cost analysis of educational media systems and summarize a good deal of evaluation research on costs. They thus provide a broad sense for planners of what the cost behaviour of media systems has been. More detailed information is required, however, for planning future media system costs and Section IV discusses in more detail the nature of the required information.

IV. Planning future system costs

My purpose in this section is to provide background information on what actual costs for elements in the cost function have been and can be expected to be. This information can serve as a guide to planners of future systems even though the estimates presented here will generally need to be changed to reflect local circumstances.

A. Central administration and start-up

Project planning, feasibility studies, and cost analyses are important initial steps before a project is undertaken. These costs should be included as part of the project costs. Unfortunately, many analyses ignore these costs as they are difficult to determine. These costs may be high if the project is one of the first projects using a particular form of technology and cannot base its analysis on other project experiences. For example, Stanford was the first university to use the Instructional Television Fixed Service (ITFS) band for television with two-way audio for off-campus education. There, start-up costs amounted to $328,000. There are now many other systems that have followed the Stanford model and these planning costs can be minimized. In Nicaragua, initial planning expenses were $268,000. This is the first system to provide a mathematics curriculum via radio for primary school students and requires 40-50 responses from each student (in a workbook) during a 30-minute lesson. This technique can probably be adapted to other Spanish-speaking countries at significantly lower cost.

Central administration is another important expense item that varies widely from project and is often ignored. For the Stanford

ITV system, people are employed full-time in an administrative capacity and their salaries total approximately $100,000 each year. Another important expense that may be omitted is for research and evaluation. In Nicaragua, evaluation of the programmes was part of a formative evaluation process and was included within production expenses. However, an additional $118,000 was spent on other research. In the Ivory Coast, expenses for evaluation of ETV have reached over $200,000 per year, and may well become higher.

B. Programme production

Production costs vary widely and depend upon the complexity of the programme being presented. As the complexity of the presentation increases, more expensive equipment and more personnel may be involved. For example, the Stanford ITV system uses one teacher, one camera operator and two cameras in the studio. The format of the programme is direct lecturing, with notes and graphs, by the teacher (the system provides a facility for student talkback), and the costs per hour for production are approximately $91. For the Mexican *Telesecundaria,* production costs are approximately $490 per hour for a more complex production arrangement involving a teacher, a director, a camera operator, a technician, and materials produced by a graphics department. The production of programmes for the Open University, which is undertaken by the British Broadcasting Corporation, costs an average of $9,600 per hour (Lumsden and Ritchie, 1975).

Although production costs and programme complexity vary widely, the research cited by Schramm (1972) challenges the need for professional production techniques in educational programmes. Schramm reviewed the literature on programme production and the impact of different production techniques on student learning. He concluded that simplicity of presentation is preferable.

> "The general conclusion that emerges from the studies of simple vs. complex treatments of material in the audiovisual media is one that should gladden the heart of a budget officer or an executive producer. More often than not, there is no learning advantage to be gained by a fancier, more complex treatment." (p. 55.)
>
> "Visual embellishments do not usually help learning unless (like directional arrows) they can help organize content that is not inher-

ently well organized or (like animation) help a viewer to understand a process or concept that is very hard to understand without such simplification. In other words, visual embellishments *per se* are not especially useful in instructional material.

"No learning advantage has been demonstrated for 'professional' or 'artistic' production techniques such as dollying rather than cutting, key rather than flat lighting, dissolves, wipes, fades, etc.

"There is very little evidence that narrative presentation ordinarily has any learning advantage over expository or that adding humor adds to learning effect" (p. 65.)

His conclusion, which is revelant to the choice between television and radio, is that there is doubt that two channels (audio and visual) have an advantage over one channel (audio or visual) when the information carried by the second medium is relevant. Therefore, although he concludes that there is no advantage to spending money for complex television production, there may also be no advantage to spending money for television instead of radio if the television production merely involves lecturing. An alternative to television production utilizing graphs, charts and notes would be radio with student workbooks or printed materials. This alternative would have the difficulty, however, that in many rural areas distribution of printed materials poses difficulties.

Schramm (1972) also found the research to suggest that active participation by the student is important:

"The chief *positive* guideline that emerges from the research is the usefulness of active student participation. Concerning that we have been able to report impressively consistent results. Participation may be overt or covert; spoken or written or done through practice with a model or a device; button pushing or asking or answering questions, or finishing what the instructor has begun to say. Different forms are more effective in different situations. Whatever the way in which students are encouraged to practice the desired responses, in most cases this activity is more effective if the students are given immediate knowledge of results—that is, told whether their responses are correct." (p. 66.)

"But at least two straightforward guidelines stand out from the research papers we have reviewed. Effective television can be kept as simple as possible, except where some complexity is clearly required for one task or another; students will learn more if they are kept actively participating in the teaching-learning process. Simple television: active students." (pp. 66-67.)

Planning a programme with active student participation can easily raise the costs of production. The Radio Mathematics Project in Nicaragua (Searle, Friend and Suppes, 1976) has relatively high production costs. The cost for programme production—which includes student workbooks, teacher guides, and approximately 40-50 active responses per 30-minute lesson—is $1,712 per hour. This cost is high for radio production (Schramm et al., 1967, estimated production costs of $250 per hour for radio programmes in Thailand) and is well within the range of production costs for television. However, if one assumes a 10-year lifetime for these programmes (which is reasonable considering the investment in planning, evaluation, and revision), the costs become $160 per hour per year (assuming an interest rate of 7.5 per cent). One reason the costs are high is the use of expatriates for several phases of programme production. If the expatriates could be replaced by Nicaraguans, the costs would be halved.

Jamison, Klees, and Wells (1976, pp. 104-107) summarized production costs for radio and television from several projects. From these project experiences, it would seem reasonable to assume production costs of $100 to $10,000 for television and $100 to $1,800 per hour for radio.

These experiences with costs may be complemented by cost estimates for single-studio facilities. Jamison and Bett (1973) estimate that a TV facility could be established for $20,000 and a radio facility for $5,000. Bourret (1973) has estimated a cost of $25,000 for equipment for a simple television studio. In the establishment of a community radio station in Canada, costs for radio station equipment were estimated at $11,000. Assuming a construction cost of $50 per square foot, a television studio facility (5,000 sq. ft.) would cost $25,000, and a radio studio facility (1,000 sq. ft.) would cost $5,000. Adding maintenance costs of 10 per cent of equipment investment and annualizing facility expenses for a 20-year period and equipment expenses for a 10-year period, total annual costs would be $8,600 and $1,220 for television and radio respectively.[1]

1. As discussed in Section III, annual costs are computed by adding recurrent costs (such as salaries) to 'annualized' capital costs (such as for studio equipment). Annualized costs of capital may be thought of as an annual rental cost; techniques for computing annualized costs are discussed in Appendix A.

For 300 hours of programming each year, this would result in costs of only $29 per hour for television and $6 per hour for radio. However, equipment and facility costs are the smallest portion of total costs for programming. The major component of production costs is personnel salaries. Assuming salaries of $5 per hour for administrators (2 hours of time per course hour), $3 per hour for teachers (10 hours of time per course hour), and $1 per hour for technicians (1.5 hours of time per course hour), personnel costs could range from $42 per hour (1 administrator, 1 teacher, and 1 technician) to $173 (2 administrators, 5 teachers and 2 technicians). Total costs for television could range from $71 to $202 per hour and from $48 to $179 per hour for radio. This estimate diverges considerably from project experiences and is a result of the assumption of very simple facilities and equipment and a possible underestimation of time input and salaries. The high time input is estimated to be 55 hours. Jamison and Bett (1973) estimate ranges of 32 hours to 320 hours of personnel time for each hour of original broadcasting. The salary estimates may be changed for different circumstances.

C. Transmission

Transmission system alternatives. There is a wide variety of transmission systems possible for television and radio. The transmission system delivers the signal from the broadcast origination point to the reception point. In general, transmission systems have two major components: the transmitter feeds the signal directly to the receivers; the interconnection component links the transmitters and the broadcast point.

Transmitters include satellites, aircraft, aerostats, terrestrial stations, and cables. The first four may be viewed as alternative means of increasing the altitude of the transmitter to provide a larger coverage area and reduce signal interference caused by high natural or man-made structures. An aerostat, as used in Korea, is a tethered helium-filled balloon with aerodynamical lift.[1] Terrestrial stations rely upon transmitter towers (2,000 feet appears to be a reasonable limit for tower height), which are often erected on

1. The Korean educational television authorities have been disappointed in the performance of their aerostat system and are examining alternatives.

mountain tops or high buildings to increase the coverage. These four choices all involve open-circuit transmission of the signal. The frequency of the signal may differ from the frequency received by standard receivers, making frequency converters necessary at the reception points. This system can limit access to the broadcast by raising the price of reception. Satellite transmission is typically at higher frequencies than is standard for receivers. The Stanford ITV system deliberately broadcasts at a high frequency from their mountain-based terrestrial station to limit access. Cables are excellent means of limiting access to the programmes and providing a higher-quality signal by eliminating many of the causes of interference.

Interconnectors include satellites, aircraft, aerostats, microwave relays, and videotape equipment. Many combinations are possible among transmitters and interconnectors to form transmission systems (clearly some of the combinations are senseless). As an example, terrestrial stations may be connected by any of the interconnector options while satellites when used as transmitters would not require interconnection.

Some of the important factors that affect the cost and choice of the transmission system are: quality of signal, ratio of receivers to population, percentage of population covered, population density, area, terrain, existing transmission facilities, type of educational facilities, and other telecommunication needs of the country. Butman (1972) reports that Grade A coverage (high quality signal) will be three times as expensive as Grade B coverage (moderate quality signal). Butman, Rathjens and Warren (1973) report much higher percentage cost increases to cover low population-density areas of Brazil and India with terrestrial transmitters and microwave relays than with satellite transmitters.

Basic cost information. We will not attempt to provide a detailed discussion of the costs of each transmitter and interconnector or an estimate of the sensitivity of costs to each of the factors mentioned above. However, we will provide some basic cost information for some of the choices and then discuss results of optimization and trade-off studies of transmission systems for specific applications.

When satellites are used as transmitters (direct broadcast satellites) the satellite cost is significantly higher than when satellites are used as interconnectors. The higher cost of the satellite results from the higher power output required to broadcast directly to simple receivers. For India, Butman, Rathjens and Warren (1973) estimated a cost of $25 million dollars for a direct broadcast satellite and $12 million dollars for a satellite used as an interconnector. Even though the direct broadcast satellite has higher power, special equipment is necessary at each reception point to amplify the signal and to modulate the frequency of the signal. The ASCEND (1967) study estimated a cost of $300 for this equipment. Butman *et al.* used the same estimate although they mentioned that costs for this equipment in India appeared to be in the range of $250-$675.

In Korea, the capital costs in 1975 for the aerostat system installation are estimated to be:

Aerostats	(2)	$2.16 million
Television transmitters	(4)	$1.48 million
Radio transmitters	(2)	$ .4 million
Telemetry command	(2)	$1.37 million
Miscellaneous		$1.10 million

It is interesting to note that the Koreans estimate that a duplicate system would cost 75 per cent more in 1976, and that there appear to be difficulties in making the system operational. The other interesting point to note is that television transmitters cost nearly twice as much as radio transmitters for the same coverage area.

This relationship between costs of radio and television coverage also appears at lower power ranges. Jamison and Bett (1973) reported prices of $5,000 for a 5-watt TV transmitter and $2,500 for a 10-watt FM radio transmitter. In combination with a 100-ft. antenna costing $6,000, the line of sight is 10 miles. For other terrestrial transmitters, Bourret (1973) reports that the VERTA project in the Philippines was able to purchase a 5-kilowatt transmitter and antenna for $40,000 and can cover an area with a 50-mile radius.

Microwave relays are a frequent choice for an interconnection. Butman (1972) estimated a cost of $4,000 per mile for a microwave relay in India. Butman also reported that a system in Ethiopia cost $6,000 per mile. Sovereign (1969) assumed that microwave relays would be 30 miles apart and that a one-channel television system would cost $1,733 per mile, a two-channel system $2,177 per mile, and a four-channel system $2,950 per mile for the microwave relay. Hundreds of audio channels can be carried as an alternative to one television channel.

For satellite interconnectors, Butman, Rathjens and Warren (1973) estimated a cost of $12 million for India. However, each transmitter would require an additional $150,000 in equipment to receive the signal from the satellite. Janky, Potter and Lusignan (unpub.) analyzed the following trade-off costs between transponder power and transmitter-receiver antennas for a three satellite-six transponder configuration:

Capital cost per transponder	*Transponder power*	*Antenna cost*
n.a.	5 watts	$66,000
$4.9 million	20 watts	$ 9,300
$9.6 million	50 watts	$ 5,800

These data allow one to determine the number of transmitter sites necessary to justify additional expense on the satellite. This is one type of trade-off decision which can be undertaken in minimizing transmission system cost. Other decisions are discussed in the next section.

Optimization and trade-offs. It was mentioned earlier in the section on transmission that existing transmission facilities may determine the choice. For example, *Radioprimaria* is charged $14.40 per hour for radio facilities that are under-utilized during daylight hours. Mayo, McAnany and Klees (1975) reported a cost of $2,100,000 for a one-channel television transmission system to cover a 100,000 square mile area in Mexico. However, they also reported that charges from commercial stations would be $318 per hour for the same area and $1,944 for a 767,000 square mile area (the entire country). Assuming a 10-year life at a 7.5 per cent interest rate for the transmission system used in education, the education system should only build its own system if broadcast exceeds 964 hours per year.

In a more general optimization analysis, Butman (1972) reported costs for different heights of transmitter towers and transmitter power and found that the minimum costs would occur using a 1,000-foot tower and a transmitter of sufficient power to reach an area with a 70-mile radius. This coverage could be obtained for $35 per square mile when grade B coverage is required.

A trade-off that is often analyzed in satellite feasibility studies is between direct broadcast satellites (D), terrestrial transmitters with satellite interconnector (R), and terrestrial transmitter with microwave interconnector (T). In analyzing these trade-offs Butman,

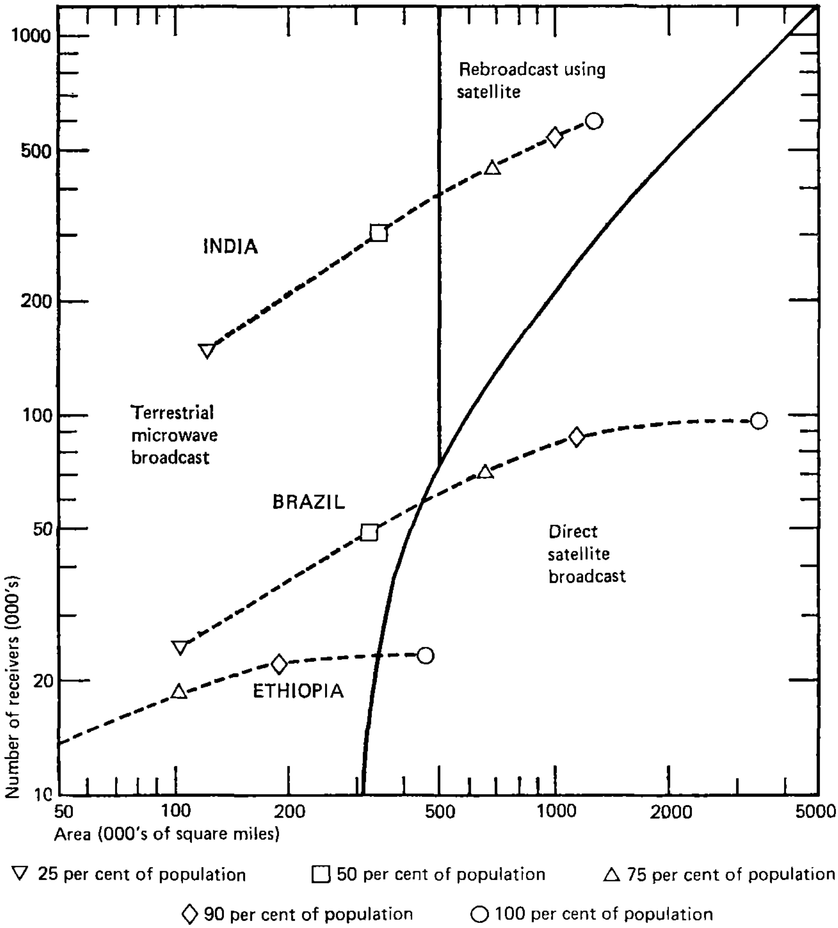

FIGURE 1. *Coverage curves: base case—one TV receiver per 1,000 people.*[1]

Rathjens and Warren (1973) made reasonable assumptions regarding costs to calculate the trade-offs among the three systems for different areas and number of receivers, as shown in Figure 1.[1] The figure reveals the combinations of area covered and number of receivers for which each system is optimal. The solid lines dividing

1. Source: G.W. Rathjens, "Communications for education in developing countries", in Butman, Rathjens and Warren (1973).

the three areas are the loci of points of equal cost. Superimposed upon this figure are shown the optimal systems for varying population coverage in India, Brazil, and Ethiopia. With an assumption of one receiver per 1,000 people the direct broadcast satellite is never an optimal choice in India. The terrestrial transmitter with microwave relay is optimal up to the point of covering approximately 60 per cent of the population. For higher coverage, the terrestrial transmitter with satellite relay system becomes optimal.

D. Reception

The main components of reception site cost include: receivers and related equipment such as antennas and cable; power supplies; and printed support materials. I discuss only receivers and power supplies here.

Receivers. There is a wide variety of receivers available for television and radio signals. In choosing a receiver, consideration must be given to maintenance requirements, reception quality, and power requirements.

Consumer Reports (1975) provided an interesting comparison of AM/FM receivers in the range of $25-$60 (list price in the U.S. in 1975). This comparison gives some indication of the relationship between initial price, battery life, and three important design characteristics: tone quality, sensitivity (ability to pick up a weak signal), and selectivity (ability to receive a station without interference from another station). Sensitivity is important, as a trade-off exists between transmitter power and receiver sensitivity. In planning a project and attempting to promote use of the programme, it may be desirable to use a transmitter with higher power to induce the purchase of lower-cost receivers with lower sensitivity. Selectivity is important in areas with multiple-channel broadcasting on closely spaced frequencies.

The general characteristics of the radio receivers tested by *Consumer Reports* are: little variance in AM sensitivity and increased FM sensitivity, AM and FM selectivity, and tone quality with price. All models used four C-size batteries. The battery life was tested by playing the radio for four hours per day at high volume (conditions that would be similar to classroom use). The batteries, which have a replacement cost of approximately $1.00 for four, lasted from six to twenty-four days.

Assuming a 5-year life for radios, a $60 radio would have an annual cost of $14.82 (at 7.5 per cent interest). Annual costs for batteries would be $12.00 assuming four hours per day for 240 days, a 20-day battery life, and a replacement cost of $1. From Table 5 one can see that a reduction in price will reduce some dimension of receiver quality. The price of radios in this analysis is higher than the price commonly used in analyses for developing countries, as these countries often use sets which receive AM frequencies only. In choosing an AM receiver, the same consideration should be given to battery life, tone quality, selectiviy and sensitivity as the comparison presented in Table 5.

TABLE 5. AM/FM radios: price, quality, and battery life

		FM		AM			
Model	Price[1]	Sensitivity	Selectivity	Sensitivity	Selectivity	Tone Quality	Battery Life[2]
Panasonic RF900	$60	VG	G	VG	F	G	17
Sony TFM7250W	$45	G	VG	VG	F-G	F	6
Penneys 1860	$50	G	F	VG	F	G	10
Hitachi KH1047H	$50	F	VG	VG	F-G	P	20
Sears 22696	$25	P-F	G	VG	F	P	19
Magnavox RD3035	$45	F	P-F	VG	G	F	18
Juliette FPR1286	$40	P-F	F	G	G	P	18
Lloyds NN8296	$30	P-F	F	G	F	P	21
Lafayette 1702349L	$28	P-F	P-F	VG	F	F	10
Soundesign 2298	$29	F	P-F	VG	F	P	24

SOURCE *Consumer Reports*, July 1975, p. 438-439.
KEY P — Poor, F — Fair, G — Good, VG — Very Good.
NOTES 1. List price in 1975 U.S. Dollars.
2. Life (in days) of four C-type batteries when set is operated for four hours per day at high volume

Television receivers can be expected to cost five to ten times as much as radio receivers. Bourret (1973) and Jamison and Bett (1973) use figures of $200 for a 23″ black and white television set. Hagerstown has been paying an average price of $150 per set, while in the Ivory Coast the price has been approximately $320.

This price may reflect a discount from list prices; retail discounts of 10-20 per cent are common and one might expect discounts on quantity purchasing direct from manufacturers.

The decision whether to use a set with a solid-state circuit or one with heavy reliance on valves has important implications. At present a valve set will cost approximately 30 per cent less than an equivalent-sized solid-state set. Through the use of printed modular circuits a solid-state set will be easier to maintain. In areas where alternatives to mainline power must be sought, the fact that a solid-state set requires only 60 per cent of the power necessary to operate a valve set can be important. A 19-inch solid-state set requires 54-60 watts whereas a valve set would require 95-100 watts. However, a solid-state set is much more sensitive to fluctuations in line voltage. A solid-state set, while requiring less power and being more easily maintained, has a higher purchase price and will require more expensive equipment for voltage regulation than a valve set.

The power requirements could be substantially reduced by using a set with a smaller picture tube. A 9-inch solid-state set would require only 32 watts. Panasonic produces a portable television receiver with a 5-inch tube and an AM/FM radio for $200. The television and radio are operated by a rechargeable 12-volt battery which has a life of 500 hours and operates for 5.5 hours between charges. However, small tubes are totally unsuitable for regular classroom viewing.

Power sources. Many areas of developing countries receive no electrical power from mains sources; for these communities, alternative power sources must be found if television receivers are to be used. Radio receivers are more readily available for battery operation. However, if a power source is available, it is preferable to have adaptable receivers, as battery operation tends to be expensive and radios have a low watt requirement. In the Ivory Coast, batteries used to provide power for a simple television cost approximately $500 and last for 2,000 hours; this is about 60 times as expensive as mains power, clearly an expensive method of operating television receivers.

There are several alternative power sources that may be considered for providing power in local communities. Rao and Manjunath (1972) investigated solar cells, thermoelectric generators, fuel cells, wind power generators, water power generators, manual power generators, animal power generators, electrical power lines, engine generators, and closed-cycle steam turbogenerators in an analysis of power sources for villages in India. They dismiss the first three alternatives as impractical due to high cost, and the next four alternatives as impractical due to lack of reliability. Their cost analysis is concentrated on power lines, engine generators (gasoline, diesel, and kerosene), and steam turbogenerators.

Ayrom (1975) discussed chemical cells, solar cells, thermoelectric generators, wind power generators, steam turbogenerators, and diesel generators for reception points in Iran. He concentrated his analysis on steam turbogenerators and diesel generators, as the other choices were assumed to be impractical.

A final important consideration is a means of storing power developed by the source. Carter (1975) reports on the use of automobile batteries for storage and estimates that 10 fully charged batteries at a cost of approximately $1,000 would deliver 65 kilowatt-hours of power (enough power for a school for 4 to 5 days). The batteries used for television receivers in the Ivory Coast store approximately 100 kilowatt-hours and cost $500. However, to charge these batteries, a wind of 20-25 m.p.h. would have to occur for 30 hours if one were using the 2,500-watt Dunlite windmill, which costs over $6,000.

Jamison, Klees and Wells (1976, pp. 117-123) provide a summary of costs and requirements of alternative power systems. The evidence they review suggests that, for powering television receivers, the best choice would appear to be turbogenerators when more than 3 miles of power line are necessary (assuming a cost of $.05 per kilowatt-hour for power-line electricity). Turbogenerators have longer lives and require less maintenance than alternative generator sources. An additional advantage of the turbogenerators is that any type of liquefied petroleum-based fuel may be used. The optimal choice depends, of course, on the peak and average power levels required, but extensions from main power lines and turbogenerators appear attractive over a fairly large range of power levels.[1]

1. Weiss and Pak (1976), in a study published subsequent to the survey by Jamison, Klees and Wells, examined the use of photovoltaic cells for powering ETV receivers remote from mains power. Though capital costs are very high, they conclude such cells to be less expensive than primary cell batteries and potentially less expensive than generators.

E. Conclusion

The purpose of this section has been to review available evidence concerning the resources required for implementing an instructional radio or television system, and to examine the current costs for these resources. Naturally costs will vary substantially from place to place and purpose to purpose; none the less the information presented in this section should provide a suitable guide for preliminary planning.

V. Conclusions

This monograph has dealt principally with the economics of the resource inputs to instructional media systems, and a number of clear conclusions have emerged. First, on the cost side, information from Section III allows us to conclude:

1. It is realistic to expect the costs of instructional radio to range from 1c to 4c or 5c per student/hour. 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.
2. It is realistic to expect the costs of instructional television to range from 5c to 15c per student/hour, or about three to five times as much as instructional radio, depending most importantly on the number of students in the system. The low end of this range can be reached only if close to a million students are using the system in a reasonably compact geographical area where main power supplies already exist.
3. Distance learning systems using radio with textbooks and workbooks can be operated at per-student annual costs of between $20 and $40 per year, resulting in potentially dramatic cost savings over traditional forms of instruction. There remains uncertainty concerning these cost estimates and examination of the economics of distance learning is a priority for research in this area.

The above conclusions concern cost, and I have dealt much less with issues of effectiveness in this monograph. Yet, given the nature of the effectiveness findings that Sections II and IV touched on, the results concerning cost have particularly important policy implications. These conclusions for policy follow:

4. Given that television seems for most purposes to work no better than radio, and that its cost and complexity of implementation is many times higher, television should almost never be used for instruction in low-income countries. Exceptions to this general conclusion might occur in those relatively rare cases when for some reason the marginal cost of TV is unusually low or when *motion* pictures are absolutely essential for instruction.
5. It is probably possible to improve the quality of in-school instruction at the elementary and secondary levels relatively inexpensively using radio.
6. Distance learning systems can reduce costs and improve access to secondary and higher education; they can, in addition, provide a mechanism for adults to receive elementary certificates without having to leave the labour force.

The relatively hopeful tone of conclusions 5 and 6 should be tempered with a reminder that the existing research has tended to focus only on success and that the research on radio and distance learning remains in its early stages. Yet the research does suggest the potential for cost-effective educational reform using radio.

APPENDIX A

Topics in cost and finance analysis of educational technology

This Appendix discusses a number of methodological aspects of examining the cost and financial structure of educational projects; it expands on the brief treatment of these subjects in Section III. Jamison and Klees (1975) and Jamison, Klees and Wells (1976) provide still more comprehensive treatments of these matters with numerous case studies.

The first two sections of this Appendix deal with the methodology of handling the time structure of costs and student utilization; the third section deals with problems of finance.

Treatment of time: annualization of capital costs

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 a 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—for example, 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 mentioned in Section III 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 per cent interest, there would be $132,560 in the bank at the end of the 10 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.[1] The total amount of this cost depends, of 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.[2] 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

1. 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.
2. Unfortunately this is the procedure used by the economists involved in the IIEP (1967) case studies of the *New educational media in action* (Schramm, Coombs, Kahnert and Lyle, 1967). Their approach overstates the cost of the media, though such a low discount rate is used (about 3 per cent) that the mistake is partially counterbalanced. Speagle (1972, p. 228), in his assessment of the cost of instructional television in El Salvador, makes the opposite and more serious mistake of including no interest charge. He justifies this in the following way: "...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." Contrary to what Speagle asserts, failure to handle capital costs appropriately can seriously understate the costs of educational technology projects, as will be demonstrated later in this Appendix. On this basis alone Speagles's cost estimates are between 20 and 33 per cent too low.

discount, r, the annualized cost of capital is given by $a(r, n)C$, where the *annualization factor*, $a(r, n)$, is given by

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

Table A.1 shows $a(r, n)$ for a number of values of r and n. When r is equal to zero, the above equation is inapplicable; $a(r, n)$ simply equals $1/n$. The derivation of this equation would lead us astray from our main purposes; we refer the interested reader to the complete account in Kemeny *et al.* (1962, Chapter VI). In our radio 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 per cent we have the following:

$$\text{annualized cost} = \frac{[0.075(1.075)^{10}]}{[(1.075)^{10} - 1]} \times 220{,}000.$$

This is equal to $32,051 per year.

It is important to realize that the use of an appropriate social rate of discount, r, is not just a theoretical nicety, but makes a significant practical difference in terms of assessing the real costs of an instructional technology project. Not to do so, that is, to use a zero interest rate, implies that the project planner is indifferent, for example, between spending a million

TABLE A.1. Values of the annualization factor $a(r, n)$

n	$r = 0\%$	$r = 7.5\%$	$r = 15\%$
1	1.000	1.000	1.000
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
20	.050	.098	.160
25	.040	.090	.155
50	.020	.077	.150

dollars now versus doing so ten years from now; such treatment can seriously understate the costs of an instructional technology project and thus make it look more favourable in a cost comparison with a traditional system, since the former usually has greater capital expenditures involved than the latter.

To illustrate the extent to which inclusion of an appropriate interest rate makes a practical difference in costing projects, Table A.2 presents the average cost per student for the projects discussed in Section III (based on the annualized cost function, evaluated for the specific year stated for each case), and depicts the degree to which such costs are underestimated if no discount rate is used (that is, $r = 0$) when the appropriate time preference for resources should be expressed by an interest rate of 7.5 or 15 per cent. We see that the percentage underestimation will vary from project to project; on the average, if no interest rate is utilized and r should equal 7.5 per cent, project costs for these cases are underestimated by 10.3 per cent, while if the true interest rate is 15 per cent, costs would be underestimated by 19.1 per cent. Although the difference in dollar amounts may appear small at first glance, it should be remembered that total project costs will be underestimated by the same percentage, and thus a small percentage difference may reflect an underestimate of true system costs that may be hundreds of thousands or even millions of dollars, depending on the extent of student utilization.

TABLE A.2. The extent of cost underestimation due to not utilizing the appropriate interest rate in analyzing ongoing instructional technology projects

Instructional technology project	Average cost per student (in 1972 U.S. dollars) at r =			Cost underestimate (%) if $r = 0$ is used and true r =	
	0%	7.5%	15%	7.5%	15%
Radio-based					
Nicaragua	3.65	3.86	4.07	5.4	10.3
Radioprimaria	12.63	13.12	13.72	3.8	8.0
Tarahumara	35.94	42.20	49.34	14.8	27.2
Thailand	0.29	0.35	0.41	17.1	29.3
Television-based					
El Salvador	19.72	24.35	29.37	19.0	32.9
Hagerstown	51.54	54.23	57.78	5.0	10.8
Korea	2.76	3.22	3.74	14.3	26.2
Telesecundaria	23.02	24.27	25.74	5.2	10.6

SOURCE Jamison, Klees and Wells (1976, p. 19).

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 Section III (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 tends 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.

Treatment of time: student utilization over time

My purpose in this section 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 programmes, and start up the operations; three or four years later these costs will have been incurred to a substantial extent and the cost picture facing the Minister is different indeed. His initial capital costs are sunk, and except for the potential (slight) resale value of his equipment, there is nothing to be recovered from abandoning the project.[1] What is desirable, then, is a method for displaying costs from the perspective of a decision-maker prior to commitment to a project, one year into the project, two 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 three years? Allowed to run for 15 years? This suggests the value of looking at average costs[2] as seen from year i of the project with a horizon through year j. I 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

1. It may none the less be wise to abandon the project—if, to be specific, still-to-be-incurred costs exceed the benefits of continuing.
2. One could also look at total and marginal costs; in my treatment here I focus on average costs because I 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.

divided by total usage of the project (number of students), with both costs and usage discounted back to year i by the social rate of discount, r.[1] 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 students served by the project in year i. Then AC_{ij} is given by:[2]

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

A decision-maker at the beginning of i can in no way influence expenditures or students 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_{ij} for various values of j. In these considerations ideally the decision-maker should base decisions on the value of AC_{ij} calculated for the j corresponding to the end of the project, for his discounting of the future is already taken into account. In the real world, however, there is a possibility that the project will be terminated

1. It may aid in understanding what follows to explain the concept of the present value of a cost. Assume that a cost of $4,000 is to be incurred 8 years from now. The *present value* of that cost is the amount that would have to be put aside now, at interest, to be able to pay the $4,000 in 8 years. If the interest rate is 6 per cent and we put aside an amount z now, in 8 years we will have $z\,(1.06)^8 =$ $4,000, or $z =$ $4,000/1.06^8. z is the present value of $4,000 8 years from now when the interest rate is 6 per cent; its numerical value is $2,509.65. The numerator of the equation for AC_{ij} 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 utilization.
2. It should be noted that the potential for the use of the AC_{ij} concept is much greater than would be indicated by the restricted definition given here, focussing on average cost per student. For example, for instructional technology project evaluation it may be as, or more, useful to think of utilization in student/hour terms and the denominator could be redefined as such. More generally, the denominator could be defined in terms of any input or output of any production process, and need not only be applied to educational evaluation. Levin (1974) has also advocated a more general utilization of what is essentially the AC_{ij} concept.

prior to its planned end, and it is thus of value to the decision-maker to see how many years it takes AC_{ij} 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 example to illustrate the concepts; Jamison, Klees and Wells (1976) apply this method of analysis to cost data from a number of actual instructional technology projects. This example assumes a project life of 6 years. In year 1 a $1,000 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 A.3 shows C_i and N_i for each of the 6 years of the project and Table A.4 shows AC_{ij} under the assumption that the social rate of discount is 7.5 per cent.

I should make a few comments about the values of AC_{ij} in Table A.4. 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

TABLE A.3. Example cost and student usage

Year i	C_i (in $)	N_i
1	1000	0
2	250	50
3	250	50
4	250	50
5	250	50
6	250	50

TABLE A.4. Example values of AC_{ij}

	Horizon year j					
Year i	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

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_{ij} 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_{ij}: if the project had a long enough life, AC_{ij} would become closer and closer to $5.00 as j got larger. AC_{ij} shows how the average cost behaviour of the project looks prior to its initiation, and the value of AC_{ij} (for j near the project lifetime value) should be important in determining whether to proceed.

The AC_{ij} estimate, like that of the average cost per student based on an annualized cost function, is also quite sensitive to the social rate of discount chosen. In fact, not taking account of social time preference (that is, utilizing a zero discount rate) usually understates the AC_{ij} measure by an even greater amount than that indicated for the annualized specific year average cost measure which we discussed. The AC_{ij} cost concept is a more meaningful summary cost measure than that provided by calculating the average cost per student from an annualized cost function, based on student utilization in one particular year. The latter figure merely gives a snapshot picture of project efficiency (in a cost sense) at one point in time, while the AC_{ij} measure captures both the history and projected plans for the particular project under consideration. In effect, an average cost per student figure is a very rough cost-effectiveness ratio that tells an analyst the resource costs of giving an individual a year's education (of given quality); it would seeem to make good sense to evaluate this particular aspect of the cost-effectiveness of a project over the project lifetime, and not for any particular year.

It should be noted that in the absence of perfect markets there is no necessary reason to choose the same interest rate for discounting both costs and students. It is entirely possible that the rate of time preference relating to students receiving an education and that associated with resource investments may be different, although in the absence of a specific notion of what this discount rate difference may be the same rate should be applied to both resources and students in the analysis of instructional technology costs.

Problems of finance

A conceptually separate issue from that of the aggregate level of, and uses for, a project's resources, which are reflected in cost functions, is that of who bears the costs. This is the problem of project finance. For major education projects the following broad categories include most potential sources of finance: multilateral and bilateral international donor agencies;

central governments; local governments and communities; and students and their families.

Understanding the sources of finance of ongoing projects and planning finances carefully for future projects, are important for at least three reasons. First, projects must cover their costs; the question of which project configurations are, and which are not, financially feasible is an important one. Second, the structure of the financing will affect project development and utilization through its incentive effects. If, for example, an international donor agency will finance only capital equipment, local project managers may have a strong incentive to design a more capital-intensive project than prevailing prices would indicate to be optimal. Or, to take a second example, if a central government requires that local communities or students bear a large fraction of the costs (in money or in kind), they can expect that utilization will be lower than if the central government provided more subsidy. This may be desirable or undesirable; the point is simply that these incentive effects are apt to be there and, perhaps, to be strong. Finally, the financing structure will have important implications for the income distributional effects of a project. The overall distributional impact of the project will be determined by the answers to the two questions: Who benefits? Who pays? Study of system finance can provide an answer to the second of these distributional questions.

Evaluations of the funding sources, motivational impact, and distributional impact of major educational projects have, to my knowledge, rarely been undertaken. Further research along these lines has high priority in light of the increased concern on the part of a number of governments and lending organizations, for example, the World Bank and the Agency for International Development, for distributional questions. Because of its importance, however, a number of tentative observations on the matter of finance follow:

1. The typical terms of repayment for loans from an international donor agency entail a substantial grant component. By grant component I mean the difference between the value of the loan received and the value of the repayment stream required to pay back the loan.[1]

In order to calculate the grant value of a loan, one must calculate the value of the repayment stream. This requires knowledge of the precise terms of the loan and of an annual discounting factor to convert future repayments into their 'present' value so they can be compared to the loan. This annual discounting factor is the sum of two components—the rate of inflation of the currency in which the loan must be repaid and the social discount rate of the recipient country. The rate of inflation of the repayment currency is clearly important; the more rapidly the currency inflates, the lower will

1. I neglect in this discussion the loss in purchasing power that may result from a loan's being tied to purchases in the lending country.

be the *real* value of future repayments. This is exactly analogous to a homeowner's repayment of a mortgage; his or her payments are fixed in, say, dollar terms and if the dollar is inflating then the real value of the payments decreases and hence he or she benefits. The social discount rate for a country is a planning concept that allows comparison of (inflation-adjusted) resources at the present with resources in the future. Most individuals (and countries) have positive social discount rates; that is, they prefer resources now rather than in the future. A country with a social discount rate of 10 per cent would be indifferent between $1,000,000 now and $1,100,000 one year from now, assuming no inflation. For the purpose of computing the grant component of a loan, a discounting factor of at least 8 per cent should be used to reflect a minimal inflation rate for hard currencies; typical values of social discount rates could take the discounting factor to a level of 15 per cent or more.

Table A.5 shows how the grant component of a loan varies with the annual discounting factor for loans with repayment terms customarily used by the U.S. Agency for International Development. Footnote 1 of the table states these terms. At a minimal discounting factor of 7.5 per cent (reflecting only inflation, and probably a low estimate for that), Table A.5 shows that the grant component of an AID loan is 57 per cent; if the discounting factor is 15 per cent, the grant component is 82 per cent. Another way of putting this is that if the discounting factor is 15 per cent, the recipient country would be indifferent between receiving a loan on the AID terms and receiving an outright grant whose value was 82 per cent of the value of the loan.

The grant component of these AID and other, similar, international development loans is thus quite high; exactly how high is determined by the (uncertain) inflation rate of the repayment currency and the recipient country's social rate of discount.

2. A second observation on finance is that existing patterns of finance for major educational projects can often impart a capital-intensive bias to them. If international loans or grants are tied to equipment purchase or major construction activities then, from the viewpoint of the local planner, these items have little scarcity value. He will tend to treat them as relatively costless in contrast to, for example, studio personnel whose salaries must be paid out of a local budget. Though this might be rational from the local perspective, it can lead to major misallocations of resources. I am aware of one example where new studio facilities were constructed with international funds even though perfectly adequate studios already existed. There are numerous examples of studios more elaborately equipped than appears to be necessary for instructional television production. As another example I expect that some of the overemphasis on TV in comparison to radio results from donor agency willingness to fund TV's substantial capital costs.

TABLE A.5. Calculated grant component of aid hard currency loans[1]

Annual discounting factor (%)[2]	A Present value of interest payments ($)[3]	B Present value of loan repayments ($)[4]	C (= A + B) Present value of all payments ($)	Percent grant[5]
5	156	480	636	36
7.5	139	291	430	57
10	125	184	309	69
12.5	112	121	233	77
15	102	82	184	82
17.5	93	57	150	85
20	85	41	126	87

1. The entries in the columns labelled A, B, and C are the present values of future repayments of a loan of value $1000 to a recipient country. The standard AID repayment schedule is as follows: (i) For the first ten years after receipt of the loan the recipient country repays the U.S. accumulated interest semiannually; the rate of interest is 2 per cent per annum. (ii) Loan repayment begins after 10 years and the interest rate charged increases to 3 per cent; the repayment schedule calls for equal semiannual payments over a period of 30 years.
2. To compute the grant component of a loan it is necessary to have a discounting factor for future repayments. This discounting factor is the sum of two items—the expected rate of inflation of the dollar and the real social discount rate of the recipient country. For simplicity of computation and because of lack of alternative information, we assume a constant discounting factor.
3. The entries in this column are the present values of the interest payment during the 10-year period prior to commencing repayment of the loan, assuming the initial value of the loan to be $1000.
4. The entries in this column are the present values of the 30-year loan repayment stream, which begins 10 years after granting the loan, assuming the initial value of the loan to be $1000.
5. This column indicates the percentage of a loan that is actually a grant; it equals 1000 minus the value of column C, divided by 1000, expressed as a percentage. The grant component increases to a high fraction of the loan as future repayments become more heavily discounted.

SOURCE Jamison, Klees and Wells (1976)

In the terminology of the previous chapter, most international finance of instructional technology is restricted to capital costs, particularly fixed capital costs. (Some goes for variable capital costs, such as receivers.) Mechanisms should be sought to allow international finance to cover more in the way of recurrent and variable costs;[1] once these mechanisms are available, lending agencies should consider explicitly the question of whether and how best to control utilization of grant and loan funds.

3. A third point concerning the financial aspects of instructional technology projects is that they are often claimed to have important favourable redistributional effects. The bases for this claim are, first, that for a given level

1. An AID loan to the elementary/middle school project of the Korean Educational Development Institute is an example of one such mechanism. The Koreans wished to put the loan in a bank and use the interest payments to finance recurrent expenses. AID consented, though apparently with some questioning on the part of their auditors.

of expenditure the technologies can provide relatively better instruction in rural areas (and in the poorer parts of urban areas), and, second, that the incidence of cost of technological approaches to instruction is more progressive than for traditional approaches. We believe that these claims are probably correct for most, but not all, existing projects, and that with proper project design the redistributive potential of investment in instructional technologies could be enhanced. We stress, however, that almost no data exist on this increasingly important matter.[1]

The preceding three points on the nature and impact of financing mechanisms for instructional technology systems point clearly to the need for more research. Though it would be desirable to know more about the pedagogical impact and cost of instructional technology systems, valuable data are available and have been analyzed. Not so for finance. We have almost no empirical information on the distributional impact of existing instructional technology systems; on the extent to which differential subsidization of system components distorts incentives; on how varying financial structures do (could) affect demand and utilization. Even limited research efforts should provide valuable information.

1. Klees (1975, chapter VI) discusses the impact on achievement inequality of the Mexican *Telesecundaria* from several perspectives. His most important conclusion from the point of view of policy was that, because of its lower cost than traditional instruction, *Telesecundaria* would be more inequality-reducing. However, it should also be noted that the financing of the *Telesecundaria*, as discussed in Klees (1975), appears to be less egalitarian than the financing of the traditional Mexican educational system.

APPENDIX B

The opportunity cost of instructional media

A slightly different, but related, notion of cost from that used in Section III is that of *opportunity cost*. The opportunity cost of a choice from among a limited set of alternatives is the value to the decision-maker (or to the society) of what he or she turned down in order to be able to choose what he or she did. In a competitive market economy the price of goods and services is one measure of the opportunity cost, as the price of that item both reflects what the user of the item gives up, since the money allocated to that item could have been spent elsewhere, and reflects the cost to the economy of utilizing its resources to produce that item, resources that could have been productive in other endeavours.

However, it is often useful, within a constrained choice situation, to examine the opportunity cost of an activity in non-price terms, as measured by the activity, or physical resources, that are given up through following a particular choice. If, for example, the superintendent tells a principal that he can have either 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. This appendix briefly discusses the means for examining such relationships arising from instructional technology system choices.

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 at present teacher salaries, we will examine the opportunity cost of introducing something new (for example, instructional television or radio) under the assumption that its opportunity cost is less teacher input. Let S be the student/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 $\frac{[W + A(S + I)]}{(S + I)}$, and the following must hold:

$$\frac{W}{S} = \frac{R[W + A(S + I)]}{(S + I)}.$$

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:

$$I = \frac{[SW(1 - R) + AS^2R]}{[W - ASR]}.$$

I represents, then, the opportunity cost of introducing a technology in terms of increased student/teacher ratio. Under the assumption that per-student costs remain unchanged, i.e., R = 1, Table A.6 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 = $1,500, A = $9.00, and R = 1, Table I.6 shows that I = 4.41; that is, the student/teacher ratio after technology is introduced equals 29.41. While the above formula was developed for expressing the opportunity cost of introducing a technology in terms of student/teacher ratio, similar formulas could be developed between other pairs of inputs. All such formulas would essentially represent ways of analytically evaluating the trade-offs within a fixed budget constraint.

TABLE A.6. Increase in student/teacher ratio required to finance technology[1]

		W = Teacher annual wage			
S[2]	A	$750	$1500	$2250	$3000
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
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

1. This table shows the increase in average student/teacher ratio that is required if per-student instructional cost (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.
2. S is the value of the student/teacher ratio before the technology is introduced.

SOURCE Jamison and Klees, 1975.

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The book

An increasing number of low-income countries are using educational radio and television in attempts to improve access to education, to reduce its costs, or to improve its quality. This book presents the educational planner with data and methods for employing cost analysis as a tool to improve decisions concerning the use of educational media. The author argues that the available data on media effectiveness suggest the central importance of cost considerations in such decisions, and concludes that while educational television will seldom be economically justifiable, there will often be a case for careful consideration of radio.

The author

An economist in the Development Economics Department of the International Bank for Reconstruction and Development, Dean T. Jamison is a co-author of *Costing Educational Media* (1977) and a co-editor of *Education as an Industry* (1977).

ISBN 92-803-1076-3