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Five analyses comparing alternative national information processing and communications systems that can be used for education and other forms of social development in less developed countries: Satellite Television: A System Proposal for India; Satellite-Distributed Educational Television for Developing Countries--Summary Report; Costs of Educational Media Systems; Excerpts from Notes on Cost-Effectiveness Evaluation of Schooling in Developing Countries; Determining the Least-Cost National System for Distributing Educational Television with Audio Feedback.

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ACADEMY FOR EDUCATIONAL DEVELOPMENT

Alternative Communications Systems for Education in the Less Developed Countries

Appendices

James G. Miller

Report Number Three
1973

This report has been prepared by the Academy for Educational Development under Contract No. AID/csd-2829 for the Office of Education and Human Resources, Bureau for Technical Assistance, Agency for International Development.

Section 220 of the Foreign Assistance Act of 1970 directs the U.S. Agency for International Development to undertake a wide array of activities aimed at assisting the developing countries in their use of communications technologies for education, agriculture, health, and community development. The technologies consist of radio, television, programmed teaching systems, computers, and communications satellites.

To carry out some of the activities mandated under Section 220, AID has contracted with the Academy for Educational Development to direct scientific research on the use of educational technology, to assess educational effectiveness and cost implications of various alternative communications systems, and to develop ways of applying electronic communications systems to agriculture, nutrition, population, and community development.

This report is one of a series prepared by the Academy and its subcontractors for AID under the terms of the contract. The reports in this series include:

1. Research and Development Priorities in Instructional Technologies for the Less Developed Countries
2. Research and Development Priorities in Instructional Technologies for the Less Developed Countries: A Summary
3. Alternative Communications Systems for Education in the Less Developed Countries
4. Broadcast Satellites for Educational Development: Possible Key Policy Decision Points, 1973-1978
5. Broadcast Satellites for Educational Development: The Experiments in Brazil, India, and the United States
6. Strategies for the Use of Mass Communications Media in the Technologically Developing Nations: Basic Education, Family Planning, and Nutrition
7. Communication Strategies for Agricultural Development
8. Communication Strategies for Development: A Summary
9. Technical-Economic Considerations in Public Service Broadcast Communications for Developing Countries

APPENDICES

INTRODUCTION

There follow five appendices, each of which is an analysis comparing alternative national information processing and communications systems that can be used for education and other forms of social development in less developed and/or established countries. They overlap in many ways, but each has its own unique characteristics and each makes its own unique contribution. They are presented chronologically to illustrate two points: (a) From the earliest (the 1968 paper of Rao, Vepa, Negarajan, Sitaram, and Nerurker) the basic issues were understood and alternative approaches were evaluated comparatively; and (b) the later papers evidence greater objectivity, sophistication of method, and precision of quantification than the earlier ones. This is the general trend of the best articles in this area of work. We still do not understand all the principles of cost-effectiveness evaluation of systems of instructional technology, but the field is advancing rapidly in understanding and rigor.

APPENDIX I

Satellite Television: A System Proposal for India

By: B.S. Rao, P.L. Vepa, N.S. Nagarajan
H. Sitaram and B.Y. Nerurker

(From Transactions of the U.N. Conference on the Exploration and Peaceful Uses of Outer Space. Thematic Session I, A/CONF. 34/I.1, 24 June 1968.)

Introduction

1. This paper* examines, in the context of the Indian situation, four possible alternative systems of providing nationwide television coverage. At the outset it must be mentioned that what is meant here by nationwide coverage is the provision of a TV receiver in each of the 560,000 villages in the country. Though many villages would be large enough to justify more than one set for community viewing, as a first step it is considered adequate to make the facility of TV available by putting a set in each village. It would not be appropriate to go into a detailed discussion on why rural coverage is emphasized. Suffice it to say, that most urban and semi-urban areas, where the rate of literacy is higher, have access to a host of mass media of communication, while rural areas are relatively isolated. Provision of television is not an end itself but a means--a very powerful one at that--to help solve the urgent problems facing the country: controlling population growth, improving agricultural productivity and eradication of illiteracy. These three problems appear to be, in order of priority, the more important ones for which TV can be used effectively for dissemination of information and bringing about a behavioral change in the rural masses. Needless to say that once installed, TV would be used for other purposes as well: social education, vocational

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* The valuable contributions made by Mr. Leonard Jaffe, Mr. Arnold W. Frutkin and Mr. A.H. Greg Andros, members of the Joint Study Group from the U.S. National Aeronautics and Space Administration, are gratefully acknowledged.

training, promoting national integration and for cultural programmes and newscasts. In a country like India where 82 per cent of the population is rural, 76 per cent is illiterate and 70 per cent is involved in agriculture, contributing half of the 32 billion-dollar gross national income, both in terms of potential use of the medium as well as need for it, there is a strong case for providing initially, nationwide rural coverage on an urgent basis. This paper considers only the government-owned community receivers to be installed in the villages and not privately-owned receivers. It is obvious that once the service is established, many people, particularly in urban areas, would want to have their own TV sets. Since currently only 58,000 villages in the country are electrified, it is expected that cheap means of power like wind and bicycle generators with accummulators and thermoelectric sources would be developed and used extensively.

Description of the Alternative Systems

2. The following four systems are considered in this paper:

(a) System A

Conventional rebroadcast stations with terrestrial microwave interconnection: This is a purely terrestrial system and requires 150 VHF TV transmitters, each of 50 KW ERP and antenna height of 500 feet. Each such station can provide Class A coverage within a radius of 50 miles (80 km) covering an area of 7,850 sq. miles (20,150 sq. kms). These transmitting stations will have to be interconnected by good quality microwave links with an estimated total route distance of 15,000 miles (24,000 kms.). About 560,000 government-owned community TV receivers, in as many villages, can

be served by these stations. Because of uncovered pockets between adjacent areas, only 91 per cent of the area and 95 per cent of the population of the country would get Class A coverage. Most of these pockets would also be covered, though the signal received there would be of a lower grade.

(b) System B

Satellite broadcasting exclusively: This is a purely spatial system. Programs originating from any one of two earth stations would be transmitted to the satellite for direct reception by the 560,000 community receivers in the villages. Though technically a single programme originating centre with facility to transmit to the satellite would do, for programmatic and reliability reasons, two satellite earth stations are proposed having transmit/receive capability. To receive programme transmissions directly from the satellite, the conventional TV receivers would have an added front-end, namely, a small parabolic dish of 1 to 3 meters in diameter and a preamplifier-converter.

(c) System C

Conventional rebroadcast stations with satellite interconnections: This system would involve 150 VHF transmitters with a distribution satellite providing interconnection between the stations. All the 150 VHF transmitting stations will require an additional receive-only facility involving a 30 foot dish antenna to enable reception from the satellite, which would be rebroadcast by the VHF transmitting stations to the local area.

(d) System D

A hybrid system with five rebroadcast stations: This is a combination of direct broadcast and rebroadcast systems. The choice between direct and rebroadcast systems would depend upon the cost of a receive-only and

rebroadcast facility, the cost of an added front-end and the receiver population density. When the cost of a receive-only and rebroadcast facility is 1.1 million dollars (vide appendices 2 and 3 for details) and the cost of a front-end is 105 dollars, the cross-over point works out to 10,450 receivers per service area of each rebroadcast station. This means that if the number of receivers to be served by a rebroadcast station is less than 10,450, direct broadcast from the satellite is to be preferred, and when the number is grater than 10,450, rebroadcast from a conventional VHF transmitter is to be preferred. The rather high figure for the cross-over point is due to the relatively expensive rebroadcast station. While the cost of a rebroadcast station may be exhorbitant by Western experience, it remains quite realistic under Indian conditions. Though the figure of $105 for the front-end is essentially an U.S estimate, it is considered realistic for India too, when made in sufficiently large lot sizes. As a result of this high cross-over point, it turns out that less than five locations in India have a village density high enough to justify the rebroadcast system. It is for this reason that for the hybrid system examined here, only five rebroadcast stations are considered.

Economic Comparison of Alternative Systems

3. Annex 1 summarizes the cost estimates for these four systems while Annex 2 shows a comparison of capital costs for the four systems with the common TV receiver cost excluded. For purposes of comparison between alternatives, all common costs should be excluded, and Annex 2 gives just this comparison which is of relevance for a decision on what is the optimal system for the

country. Annex 3 contains a detailed estimate of the capital as well as the annual maintenance costs for this system. From Annex 1 it is evident that System D, namely, a hybrid system with five rebroadcast stations is the optimal one for India giving the least cost solution at a total cost of $224.04 million, including the cost of the satellite in orbit. It is interesting to note however, that System B, namely, exclusive broadcast from the satellite comes a close second, at a total cost of $225.05 million. It is also seen from Annex 2 that a purely terrestrial system (a) costs 3.24 times more than a hybrid system (d) using a synchronous satellite. Annex 4 gives the basic estimates used for the calculations and Appendices 1 to 4 give the cost break-up for various items.

Need for a Pilot Project

4. From the foregoing, it is clear that establishing a countrywide TV system for purposes of national development is a stupendous task. The problems involved are many-fold: financial resources, man-power, problems of technology, physical resources (industrial base required) and lastly organizational and social problems in making the system viable. What is really being attempted here is to deploy sophisticated technology to bring about a basic change in the individual's behaviour through the use of a medium of proven potential. The successful persuasion of a peasant to try a new farming technique or of a village girl to practice family planning is not an easy job in a tradition-oriented rural society. It is widely recognized that in this whole process, the pace of progress in technology has far outstripped that in the field of social sciences and

in our understanding of human behaviour and motivation necessary for effective programming. The problems of programming are compounded by the diversity in the country: there are more than 80 distinct agricultural regions categorized on the basis of cropping pattern, soil and climatic conditions etc, 14 major languages and great cultural and socioeconomic variations in the country. Added to these are the organizational and managerial problems in a country like India where much of the initiative for an effort like this is from the State.

5. To test the effectiveness of television as a medium of mass communication as well as to gain insights into the social and organizational problems using television, a pilot project was started in Delhi in January 1967.[1] While the results of this project have on the whole been encouraging, it is also evident that much caution needs to be exercised before the Delhi project proliferates on a national scale. In the past, encouraged by the success of a project of limited size like the Radio Rural Forums initiated in Poons, the effort was duplicated in many parts of the country but with rather disappointing results.[2] To avoid recurrence of such happenings, it is proposed that the satellite television system should be undertaken on a limited scale as a pilot project, to begin with.

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1 "Opportunities available to developing nations through the use of communication satellites: the Delhi Project," a paper submitted by India for Thematic Session VII.

2 Vide "Ten years of the Radio Rural Forum in India" by Wilbur Schramm in New educational media in action: case studies for planners-I,

6. Para 9 contains a definition of the proposed pilot project, planning for which is being done with the kind and active cooperation of the U.S. National Aeronautics and Space Administration. As is well known, the Unesco Expert Mission which visited India in November/December 1967 submitted a report on a preparatory study of a pilot project in the use of satellite communication for national development purposes in India. As this has been widely circulated no effort is made here to describe it.

7. Objectives of the Proposed Pilot Project

(a) Management Objectives

The most crucial aspect of the project would be to work out a viable social and organizational structure with a proper feedback system for effective communication and control. This assumes added significance since this project is unique in the sense that it calls for cooperation between more than six government organizations.

(b) Technical objectives

The basic technical objective of the proposed pilot project is to demonstrate and to conduct a systems test of the hybrid mode of satellite television for national development. An attempt would be made to assess the impact of the programmes under different conditions defined by parameters such as population density, birth rate, socio-economic strata, rate of literacy, availability of mass media, cropping pattern etc. Technical objectives may be grouped under three broad categories:

(i) development (design and fabrication of the ground segment)
(ii) operation
(iii) maintenance

(i) Development objectives: Here the objective would be to design and fabricate the following:

a. Earth stations (transmit and receive capability)
b. 30 foot dish antennas
c. Ruggdeized community TV receivers
d. Front-ends for direct TV receivers
e. Ten-foot roof-top antennas

(ii) Operational objectives: This would relate to an assessment of the following:

a. Performance data (mean time before failure, optimal duty cycle etc.) of various equipments.
b. Grade of service (picture quality) vs. learning.
c. Picture quality of direct vs. rebroadcast transmissions under varying conditions and locations of receivers.
d. Accommodation of more than one audio channel; problems of lip synchronisation, frequency separation between video and audio etc.

(III) Maintenance objectives: Here the objectives would be to assess and meet the maintenance requirements with regard to the following:

a. Earth stations
b. VHF Television transmitting stations
c. Community receivers (direct as well as conventional)

8. The design, development and manufacture of TV receivers has been initiated in India and it is expected that annual production would reach 30,000 in 1969 and about 50,000 in 1970. Community TV sets have to be necessarily rugged in design for easy operation and minimal maintenance in the field. Receiver maintenance being the most crucial factor, it is proposed that well equipped maintenance centres be established at the same site as the VHF station to service the conventional receivers and at suitable and central locations to service clusters of direct receivers.

Description of the Proposed Pilot Project

9. It is felt that the pilot project should involve a minimum of 5,000 community receivers, taking into account the number of experiments and the various conditions under which they would be conducted. An additional 10 per cent would be retained as standbys for quick replacement. Of these, 3,000 receivers would be conventional community sets to be served by 3 VHF rebroadcast stations and the remaining 2,000 would be for direct reception. One of these VHF stations is already in operation in New Delhi; the second would be located in a rural area within easy linking distance of the Experimental Satellite Communications Earth Station at Abmedabad. The location of the third rebroadcast station as well as of the 2,000 direct receivers, scattered in about four areas, would be decided depending upon the precise requirements of the various studies to be made. The set-up for the pilot project will consist of one earth station transmitting programmes to the satellite and three receiver-only earth stations for receiving programmes for rebroadcast to the local areas. For the pilot project it appears that one video channel with two audio channels would be adequate. The language problem would be tackled essentially by different regions using the satellite on a time-shared basis. Annex 5 gives on estimate of the ground-segment costs for the pilot project, which total to 6.64 million dollars. It is envisaged that most of the items for the ground segment would be produced in India.

10. Details of the satellite required are not being spelled out here since this paper essentially deals with the nature of the ground segment. While for the pilot project, the possibility of utilizing the ATS F/G satellite

for a limited period is being explored with the U.S. National Aeronautics and Space Administration, it is evident that for a country like India a national or regional satellite will soon become a necessity. Though the fabrication of a satellite can be contemplated by India, being a developing country with no capability to launch a satellite in the near future, she will have to rely on an advanced nation for this. An invaluable contribution the advanced nations can make is assuring the launch of TV satellites for the developing countries without predicating it to the state of the political equation between the countries involved. As suggested by India in the paper[3] submitted at the fifth session of the Scientific and Technical Subcommittee of the Committee on the Peaceful Uses of Outer Space, held in New York in August/September 1967, a synchronous satellite located over the Indian Ocean could be used by the developing Afro-Asian countries for relaying television on a time-shared basis. No single development can perhaps alter the face of the developing countries as television via satellites can. The social, political and legal implications arising out of the dependent roles caused by this development are matters for the serious and urgent consideration of the international community.

Evaluation

11. The effectiveness of the programmes would be evaluated in tangible terms in a systematic manner on a before-and-after basis. The precise criteria for the evaluation are not being spelled out here; suffice it to say that many institutions and universities have the professional expertise to undertake this kind of work. The design of the evaluation scheme would

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3 "Satellite Communications: An Indian Study" (U.N. Document No. A/AC. 105/36).

be such as to measure the influence of various environmental parameters on the effectiveness of the programmes. The overall validity of the experiment as well as the lessons learned from it would be studied by analysis of the results and continual review of its progress so as to serve as guidelines for planning an expanded system.

ANNEX 2

CAPITAL COST COMPARISON OF THE DIFFERENT SYSTEMS WITH COMMON TV RECEIVER COST EXCLUDED

Systems	In millions	
	Rupees	U.S. $
A. Conventional rebroadcast stations with terrestrial microwave interconnection	1,851.00	245.60
B. Satellite broadcasting exclusively	577.75	77.05
C. Conventional rebroadcast stations with satellite interconnection	1,328.65	177.15
D. Hybrid System with 5 rebroadcast stations	571.40	76.04

ANNEX 3

COST ESTIMATE FOR SYSTEM D
D. Hybrid System with 5 rebroadcast stations
(All figures in millions)

Description	U.S. $		Indian Rs.	
	Initial Cost	Annual Maintenance	Initial Cost	Annual Maintenance
1. Earth Stations (2) (Transmit & receive capacility)				
a) Land (50 acres @ Rs.60,000 each)	0.40	..	3.00	..
b) Buildings @ Rs.500,000 each	0.13	0.01	1.00	0.02
c) Equipment @ Rs.5.7 each	1.52	0.15	11.40	1.14
2. Satellite in orbit (Hughes estimate)	10.30	..	77.25	..
3. VHF Transmitters (5)				
a) Land @ Rs.600,000 per station	0.40	..	3.00	..
b) Building @ Rs.800,000 per station	0.53	0.01	4.00	0.08
c) Equipment including airconditioning	4.06	0.45	30.50	3.40
4. *Earth Stations Receive capability (3) @ Rs.750,000 each	0.30	0.01	2.25	0.05
5. TV receivers (616,000) @ Rs.1,800 each	148.00	7.40	1,109.00	55.45
6. +Receive front-ends @ Rs.787.50 each 559,625 (508,750 + 10%)	58.40	1.75	439.00	13.17
	224.04	9.78	1,680.40	73.31

* Two more receive stations would be located along with the two transmit stations. As the receive-only stations would be located at the rebroadcast stations, no separate amount is shown for land and buildings for these.

\+ When the cost of a receive-only and rebroadcast station is $1.1 million and the cost of a front-end is $105, the cross-over point works out to 10,450 receivers per service area. The five rebroadcast stations would cover 57,475 conventional receivers and the remaining 508,750 villages would have direct receivers.

ANNEX 4

BASIC ESTIMATES
(All figures in millions)

		Rs.	U.S. $
*1.	Cost of Satellite Earth Station (Transmit and Receive capability)	11.25	1.5
*2.	Cost of conventional VHF Transmitter (installed)	7.50	1.0
*3.	Cost of Satellite-Ground Receive-only facility	0.75	0.1
*4.	Cost of conventional TV receiver	0.0018	0.00024
5.	Cost of front-end for TV receiver (average of GE and Jansky & Bailey estimates)	0.0007875	0.000105
6.	Cost of satellite in orbit (Hughes) estimate for HS-309)	76.00	10.10
7.	Transport vehicle for maintenance (Jeep)	0.02	0.0027
	Maintenance costs:		
a)	Receiver maintenance (staff and spares)	5%	
b)	Electrical and Electronic spares	3%	
c)	Earth Station (Receive capability)	2%	
d)	Earth Station (Transmit capability)	10%	
e)	Microwave links	5%	
f)	Jeeps (maintenance and running costs)	20%	
g)	Buildings	2%	
h)	Land	Nil	
	Rate of Depreciation:		
a)	TV transmitters and Earth Station equipment	6.66%	
b)	TV receivers and front-ends	20%	
c)	Satellite (Hughes estimate)	20%	
d)	Microwave links (Indian estimate)	6.66%	
e)	Jeeps	10%	
f)	Buildings	2%	
g)	Land	Nil	

*Break-up in appendices attached.

ANNEX 5

DETAILS OF GROUND SEGMENT COST FOR THE PROPOSED PILOT PROJECT

	In millions	
	Indian Rs.	U.S. $
1. One Earth Station (Transmit and Receive capability) @ $ 1.5 million	11.25	1.50
2. Two Earth Stations (Receive-only capability @ $ 0.1 million each	1.50	0.20
3. Three VHF Transmitting stations @ $ 1.0 million each	22.50	3.00
4. 3,300 (3,000 + 10% as standbys) conventional TV receivers @ $ 240 each	5.94	0.792
5. 2,200 (2,000 + 10% as standbys) TV receivers for direct reception @ $ 345 each	5.72	0.764
6. 30 Jeeps for receiver maintenance @ Rs.20,000 each	0.60	0.080
7. Five receiver maintenance centers		
a) Land @ Rs.60,000/ - per center	0.30	0.040
b) Buildings @ Rs.200,000 per center	1.00	0.133
c) Test equipment @ Rs.200,000 per center	1.00	0.133
Total	49.81	6.642

Since an Earth Station (with Transmit/Receive capability) at Ahmedabad and a VHF station at New Delhi are already functioning Government of India would have to spend only about Rs.32 millions ($ 4.2 millions).

APPENDIX-1

Cost of a Satellite Earth Station: (Transmit/Receive capability)

	In millions	
	Indian Rs.	U.S. $
Antenna (30' dish)	1.500	0.20
Transmitter	1.050	0.14
Power amplifier and accessories	0.375	0.05
Test equipment	1.500	0.20
Receive chain and monitoring facilities	0.750	0.10
Miscellaneous	0.525	0.07
	5.700	0.76

APPENDIX-2

Cost of a Conventional VHF Transmitter

	In millions	
	Indian Rs.	U.S. $
Land	0.600	0.08
Buildings	0.800	0.11
Transmitter and monitoring equipment	1.600	0.21
Antenna	3.000	0.40
Test instruments and tools	0.210	0.03
Power supply	0.200	0.03
Airconditioning	0.150	0.02
Capital spares	0.600	0.08
Miscellaneous	0.340	0.04
	7.500	1.00

APPENDIX-3

Cost of Satellite-Ground Receive-only facility

	In millions	
	Indian Rs.	U.S. $
Antenna (30')	0.500	0.0067
Receive chain	0.250	0.033
	0.750	0.100

APPENDIX-4

Cost of a conventional TV Receiver

	Indian Rs.	U.S. $
Cost of TV receiver	1,500	200.00
Antenna	140	18.67
Tax	160	21.33
	1,800	240.00

APPENDIX II

Satellite-Distributed Educational Television for Developing Countries--Summary Report (Vol. I)

By: Wilbur Schramm & William J. Pratt

(From Stanford Research Institute Project 7150. Prepared for the Agency for International Development under Contract AID/csd-1901, August, 1968.)

INTRODUCTION

Satellite communication would appear to offer potential for accelerating the modernization process in developing countries. Distant cities and villages in a single country or a multinational region can be linked by satellite as easily as adjacent cities. The source of programming can be any properly equipped transmitting ground station. The same message or lesson can be received simultaneously by all stations that are equipped to receive the satellite signal. A satellite communication network need not wait for the construction of expensive terrestrial microwave links.

The satellite technology used to distribute ETV (educational television) may therefore provide the key for solving several stubborn problems of human resources development. Not only can it overcome terrain and distance, it may also be able to reform and modernize educational systems more rapidly than would otherwise be possible, give more people access to education and training, place the best teachers within reach of large audiences, help to integrate large sectors of the population into the social, economic and cultural life of the nation or region, and contribute to international understanding. Skillfully programmed, satellite-distributed ETV may be able to overleap the literacy barrier by bringing illiterates into some participation in the modern sector. If the technology realizes only some of these promises, it can help to accelerate economic and social development.

To explore some of the potentials of satellite communication, the U.S. Agency for International Development and the President's Task Force on Communications Policy commissioned SRI to make case studies of two developing regions. The regions India and Latin America were selected to reflect a variety of conditions, with the hope that some generalizations for other developing areas could be based on findings of the research.

India represents the case of a single nation with a population of 500 million, but sufficiently compact that it has only one time zone, while Latin America represents a multinational region in both northern and southern hemispheres and has six time zones. India is a nation of villages: 80 percent of its population reside in 568,000 villages. A larger fraction of Latin America's population is concentrated in large urban areas separated by sparsely populated rural, mountain, desert, and jungle areas.

Several types of diversity affecting the design of communication systems are present in the two case regions. In India, 15 official languages are spoken--13 of them by more than 10 million people each. These languages are built deeply into the local cultures; people in a linguistic group have been known to burn trains that come into their areas with words in another linguistic alphabet painted on the coaches. Latin America, on the other hand, has but two main languages, although many Indian languages are spoken in the interior and in the mountains. Latin America's political diversity offers a complex challenge to a communications system that can span part or all of its 23 independent nations. In both regions there is considerable agricultural diversity.

There is also a range within each region and between the two regions with respect to the generally accepted indicators of modernization--industrialization, urbanization, literacy, per capita income, fractions of age cohorts enrolled in each level of schooling, and use of mass communication media. With respect to the last indicator, only 6,000 television receivers are in use in all of India, whereas over six million receivers were in use in Latin America in 1964.

In view of the characteristics of the two case settings and the respective interests of leaders to whom the study team members spoke, potentials for satellite communications technology in the two regions were examined from slighly different viewpoints. In India, an attempt was made to answer the following question: how might satellite communication technology be used to help India achieve overall development objectives, a central one of which is national integration for the many language and cultural groups? This problem was the preoccupation of the Indian leaders and planners interviewed during the field work. In Latin America, the question examined was of somewhat narrower scope, reflecting the more advanced state of broadcasting there and the concerns of Latin American officials: what can satellite communication technology contribute to the human resources development (education and training) objectives of individual countries and of the emerging Latin American community? In Latin America, there already exists for most urban areas a commercial television system and some applications of ETV.

Thus, the question examined in India was the fundamental one of proposing an entirely new national television system in the light of the availability of satellite technology. In Latin America, the question was

more sharply focused on the prospects for ETV relevant to the capabilities of satellite technology.

Satellite communication technology must be studied in context. Successively wider angles of vision would show that satellite communication technology is imbedded in educational broadcasting; educational broadcasting in the overall education and training system; and the education and training system in a country or region's economic and social development program. This context dictated the designs for the case studies. The logic of this design for the Latin American study is presented in Figure 1. Human resources development objectives were considered in the light of national and regional development objectives. Opportunities for broadcast media to help in achieving these human resources objectives were identified, and estimates were made of the present and projected demand for such applications of media. Preliminary system designs appropriate to the demand estimates were prepared, using alternatives of satellite and terrestrial delivery links. Cost, feasibility, and organizational implications of the alternatives thus generated were examined. The Indian study, designed for a country with very little television, had to begin at an earlier stage of mass communication development, as Figure 2 illustrates.

FIGURE 1

STUDY DESIGN

SATELLITE-DISTRIBUTED ETV IN LATIN AMERICA

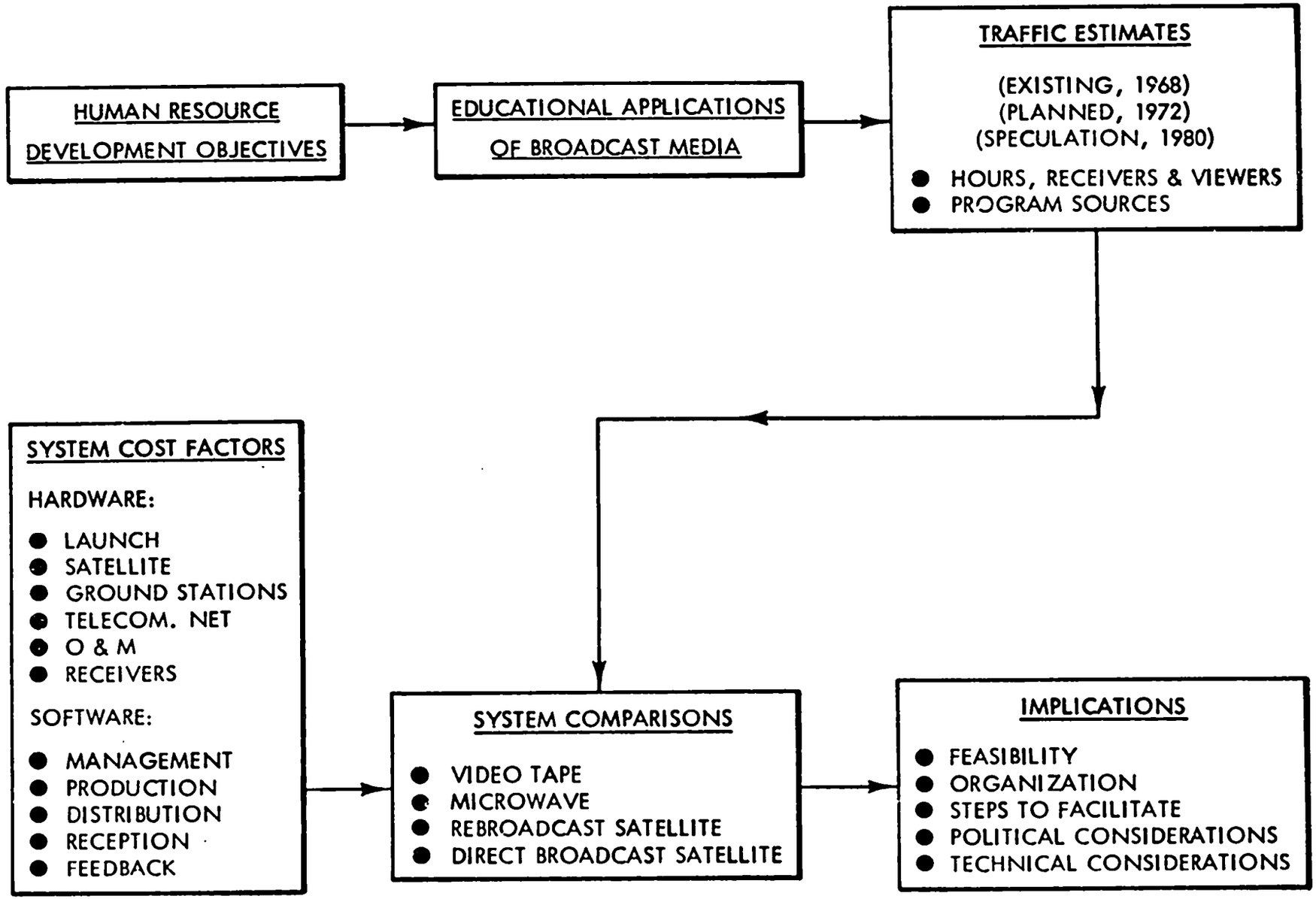
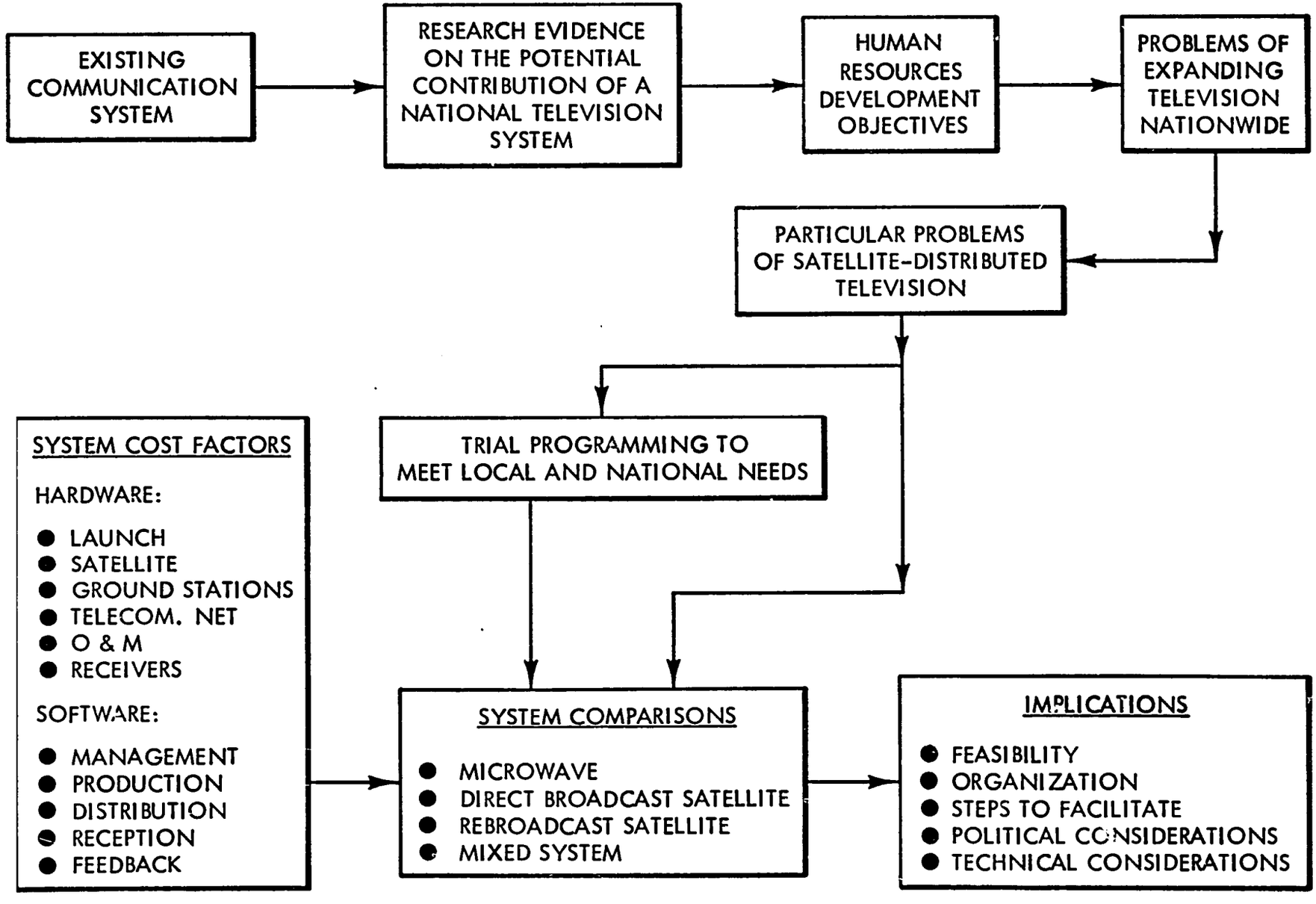


FIGURE 2

STUDY DESIGN

COMMUNICATION SATELLITES FOR EDUCATION AND DEVELOPMENT IN INDIA



APPLICATIONS OF ETV

In several Latin American countries, ETV is already contributing to the achievement of certain priority objectives for human resources development; for example, improvement of primary education in Colombia and Venezuela, accelerated secondary education in Brazil, and the provision of secondary education to students in Mexico who would otherwise lack access to such schooling. These applications appear to be most effective when ETV has been planned and managed as a system for pacing students and teachers as well and when special attention has been given to reception, thereby bringing the classroom teacher into full partnership with the studio teacher and program producer. This observation is supported by the growing body of research findings on the effectiveness of ETV.

ETV holds a significant, and sometimes a unique, potential for accelerating the achievement of the following development objectives stated by many Indian and Latin American leaders:

- Upgrade primary and secondary education by sharing the best teaching and the best demonstrations, thus more nearly equalizing the learning opportunities for all students.
- Modernize curriculum content throughout an entire educational system without having to wait for the training and retraining of the teaching staff.
- Reform teaching processes to encourage inquiry-oriented, problem-solving learning instead of tradional rote-memory instruction.

- Offer educational opportunities for the many who were unable to complete primary, secondary, or higher education cycles, but who now want to participate more fully in the labor force and in society.
- Strengthen the vocational and technical components of education to increase the relevance of training to employment opportunities.
- Offer new mathematics and new science instruction in secondary schools and in the basic cycles of higher education.

Indian officials added the following objectives that television could help to attain:

- Provide a common element in experience to further the goal of national integration.
- Bring about awareness of and interest in the family planning problem more swiftly and widely than otherwise possible.
- Assist in modernizing agriculture, and in general help to make rural life pleasant and rewarding enough to keep more of the ambitious and better-educated young people in the villages, where they are so badly needed.

DEMAND ESTIMATES

For both regions, the study teams interviewed local planners and media experts to estimate the amount and types of ETV programming that would be responsive to the foregoing objectives. These estimates were projected from the present to 1980 in Latin America and to 1988 in India. In the Indian case, special attention was given to preparing an illustrative program schedule that would go as far as possible in serving the needs of each of the major language and cultural groups found in India. This schedule shows that it would be possible, using a satellite with one video and two audio channels, to furnish weekly, for each of four languages: ten hours of school programs; nine hours of teacher training, vocational training, and literacy classes; nearly four hours of news and public events; three hours of agriculture, health, and family planning programs; two hours of children's programs; and nearly six hours of general cultural and entertainment programs. Using a satellite with three video channels and receivers equipped with two audio channels for each video channel, the foregoing amount of programming could be available for each of the 12 largest language groups in India.

In Latin America, ETV programming must also be localized, but for different reasons from those in India. First, there are the differences in school calendars, with nations in the south using the southern hemisphere schedule of February to November and those to the north using the school year of September to June. Next, there is the problem of six time

zones. And finally, there are the political considerations implicit among 17 sovereign Spanish-speaking nations, where one nation's course in history or geography may be heard in a neighboring country as propaganda.

Throughout the field work in Latin America, key personnel in education and training in each country were asked to assess the prospects for exchanging or sharing instructional programs among several countries. Most of the responses were pessimistic. Several obstacles were cited: variation in stages of economic development within Latin America; differences in political ideology and stability; differences in regional dialects and word meanings; differing interpretations of history; and the absence or weakness of educational, cultural, and economic ties between countries. (Many Latin American countries have more fully developed relationships with countries outside the continent than with their neighbors.)

A precondition for accepting common instructional programs would be efforts to harmonize curriculum content. Although committees of the Organization of American States have been formed to examine common curricular problems, only some cooperative efforts among Central American countries and beginning discussions of primary textbook cooperation among Venezuela, Colombia, and Ecuador have produced results so far. The most optimistic estimate of this study is that 25 percent of school broadcast time on Latin American satellites might be shared by 1980, given present educational diversity and political barriers.

The hours of programming per week required for the various applications of ETV can be summed to determine the number of ETV channels

required. In the Indian case, three ETV channels were projected as a realistic estimate of what India can afford and use fully in the near future. These three channels can easily be accommodated on a single satellite. In the Latin American countries where ETV is expected to grow most rapidly--Colombia and Brazil--four ETV channels each were projected for 1980. Either three or two channels were projected for each of the other countries studied. For the combined needs of 15* Latin American countries, a total of 14 ETV channels are likely to be needed by 1972, and 30 ETV channels by 1980. The larger number of channels for Latin America reflects the many national requirements, the assumption that about one-quarter of programmed hours will be shared internationally, and the advanced state of television development there. Three satellites could handle the 30 channels projected for 1980: one serving Mexico, Central America, Colombia and Venezuela; one serving Brazil; and a third serving Argentina, Bolivia, Chile, Peru and Uruguay.

The other dimension of ETV demand (in addition to hours per week of programming) is number of viewers or students served. For the Latin American case, this was estimated for participants in instructional programming, that is, for situations in which reception is organized and a classroom teacher or monitor is present. Estimates were prepared for 1968, 1972, and 1980 for each of 12 educational applications.

The product of the number of viewers multiplied by the hours per week that those viewers are engaged in watching instructional programs

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* The time available for the project permitted including only 15 of the 23 Latin American countries.

is a useful measure of demand. It is a better measure than the number of viewers unweighted by programming frequency and intensity, because some educational programs may appear only one-half hour per week, while other applications may be shown daily in both the morning and afternoon. Table 1 has been prepared from the Latin American demand estimates for 1968, 1972, and 1980 to reflect this measure of viewer hours per week. If the number of viewer hours per week is expressed as an index of 100 for 1968, the index for 1972 would be 212, and for 1980, 1,410. In other words, in 12 years a 14-fold increase could be expected. The number of students reached by organized reception would increase from the present figure of 630,000 to over 10 million in 1980.

In the Indian case study, the planning for an entire television communication system put emphasis on estimating overall demand of viewers reached by public information programming and other applications supporting the objective of national integration. Therefore, estimates of viewer hours in organized reception were felt to be too speculative and were not prepared. A phased development program was prepared, however, with the goal of making television available to 80 to 85 percent of the Indian people within 20 years.

Table 1

LATIN AMERICAN DEMAND FOR ETV APPLICATIONS IN VIEWER HOURS PER WEEK: 1968, 1972, 1980
(Viewer Hours per Week in Thousands)

ETV Application	Central America			Mexico			Colombia		
	1968	1972	1980	1968	1972	1980	1968	1972	1980
Adult education	--	--	100.0	375.0	750.0	750.0	--	70.0	500
Teacher training, preservice	--	6.0	152.0	--	--	50.0	--	50.0	176
Teacher training, inservice	--	20.0	4.4	0.8	6.6	3.0	3.6	10.0	23
Primary education, kindergarten	--	--	165.0	--	--	600.0	--	--	175
Primary education	--	9.1	10,395.0	30.0	150.0	--	585.0	6,750.0	57,200
Secondary education	--	2,000.0	6,000.0	130.0	2,500.0	7,500.0	--	300.0	5,400
Technical training	--	--	20.0	--	--	60.0	--	--	50
Higher education, science & math	--	--	60.0	90.0	180.0	600.0	0.5	60.0	150
Higher education, lecture series	--	--	--	--	--	70.0	--	--	17
Higher education, TV college	--	--	--	--	--	45.0	--	--	
Higher education, continuing professional	--	--	4.0	--	--	35.0	--	--	15
Total		2,035.1	16,900.4	625.8	3,586.6	9,713.0	5,854.1	7,240.0	63,706

ETV Application	Venezuela			Brazil			Argentina		
	1968	1972	1980	1968	1972	1980	1968	1972	1980
Adult education	--	--	--	200.0	480.0	1,500.0	--	--	--
Teacher training, preservice	--	--	92.0	--	--	208.0	--	--	44.0
Teacher training, inservice	0.2	0.5	11.0	--	--	34.2	--	--	2.2
Primary education, kindergarten	27.0	120.0	175.0	--	--	385.0	--	--	125.0
Primary education	225.0	1,125.0	15,625.0	60.0	180.0	30,000.0	--	--	4,625.0
Secondary education	30.0	30.0	2,250.0	22.5	60.0	3,510.0	--	--	1,200.0
Technical training	--	--	40.0	39.0	110.0	216.0	--	7.5	60.0
Higher education, science & math	--	90.0	150.0	--	--	120.0	--	2.0	300.0
Higher education, lecture series	--	--	17.5	--	--	--	--	--	35.0
Higher education, TV college	--	--	30.0	--	--	120.0	--	--	60.0
Higher education, continuing professional	--	--	10.6	--	--	--	--	--	58.0
Total	282.2	1,365.5	18,401.1	321.5	830.0	36,093.2		9.5	6,509.2

Table 1 (concluded)

ETV Application	Bolivia 1968	Bolivia 1972	Bolivia 1980	Chile 1968	Chile 1972	Chile 1980	Peru 1968	Peru 1972	Peru 1980
Adult education	--	4.0	75.0	--	--	--	--	28.0	125.0
Teacher training, preservice	--	--	12.0	--	--	40.0	--	--	16.0
Teacher training, inservice	--	--	1.4	--	6.0	4.5	--	--	4.4
Primary education, kindergarten	--	--	35.0	--	--	45.0	--	--	60.0
Primary education	--	--	1,412.5	--	--	6,250.0	9.1	22.5	12,500.0
Secondary education	--	--	120.0	--	--	1,500.0	--	--	1,500.0
Technical training	--	--	--	--	--	50.0	--	--	30.0
Higher education, science & math	--	--	--	--	--	150.0	--	--	37.5
Higher education, lecture series	--	--	--	--	--	17.5	--	--	--
Higher education, TV college	--	--	--	--	--	--	--	--	--
Higher education, continuing professional	--	--	2.0	--	--	8.4	--	--	10.0
Total		4.0	1,657.9		6.0	8,065.4	9.1	50.5	14,282.9

ETV Application	Uruguay 1968	Uruguay 1972	Uruguay 1980	Total 1968	Total 1972	Total 1980
Adult education	--	--	--	575.0	1,332.0	3,050.0
Teacher training, preservice	--	--	16.0	--	56.0	822.0
Teacher training, inservice	--	--	0.7	4.6	43.1	89.0
Primary education, kindergarten	--	--	25.0	27.0	120.0	1,790.0
Primary education	4.0	4.0	1,500.0	6,178.1	8,240.6	139,507.5
Secondary education	--	--	450.0	182.5	4,890.0	29,430.0
Technical training	--	--	--	39.0	117.5	526.0
Higher education, science & math	--	--	7.5	90.5	332.0	1,575.0
Higher education, lecture series	--	--	--	--	--	157.5
Higher education, TV college	--	--	--	--	--	255.0
Higher education, continuing professional	--	--	--	--	--	143.0
Total	4.0	4.0	1,999.2	7,096.7	15,131.2	177,329.0
Index				100.0	212.0	1,410.0

SYSTEMS COMPARISONS

Very preliminary designs of systems were prepared to provide the amounts of service responsive to the demand for ETV estimated for the next 12 to 20 years. For both India and Latin America, the following three distribution systems were designed:

- Microwave network linking ground-based stations
- Rebroadcast satellite linking ground-based transmitters
- Direct broadcast satellite linking ground transmitters with augmented television receiving sets

For Latin America, a fourth system was also designed:

- Truck or air shipment of video tapes linking groung-based stations.

The four distribution systems are illustrated in Figure 3. The alternative of video tape distribution was not considered for India, because it does not permit simultaneous national reception. Timeliness is not essential in school broadcasts, but news, public events, and other elements of a general communication service often must be timely to be effective. For India, another distribution system was examined:

- A combination of ground stations and direct broadcast from a satellite.

Table 2 is intended to summarize the performance of the four ETV distribution systems according to qualitative and quantitative criteria. A relative rating of excellent, good, fair, or poor has been assigned to

FIGURE 3

ALTERNATIVE ETV DISTRIBUTION MODES

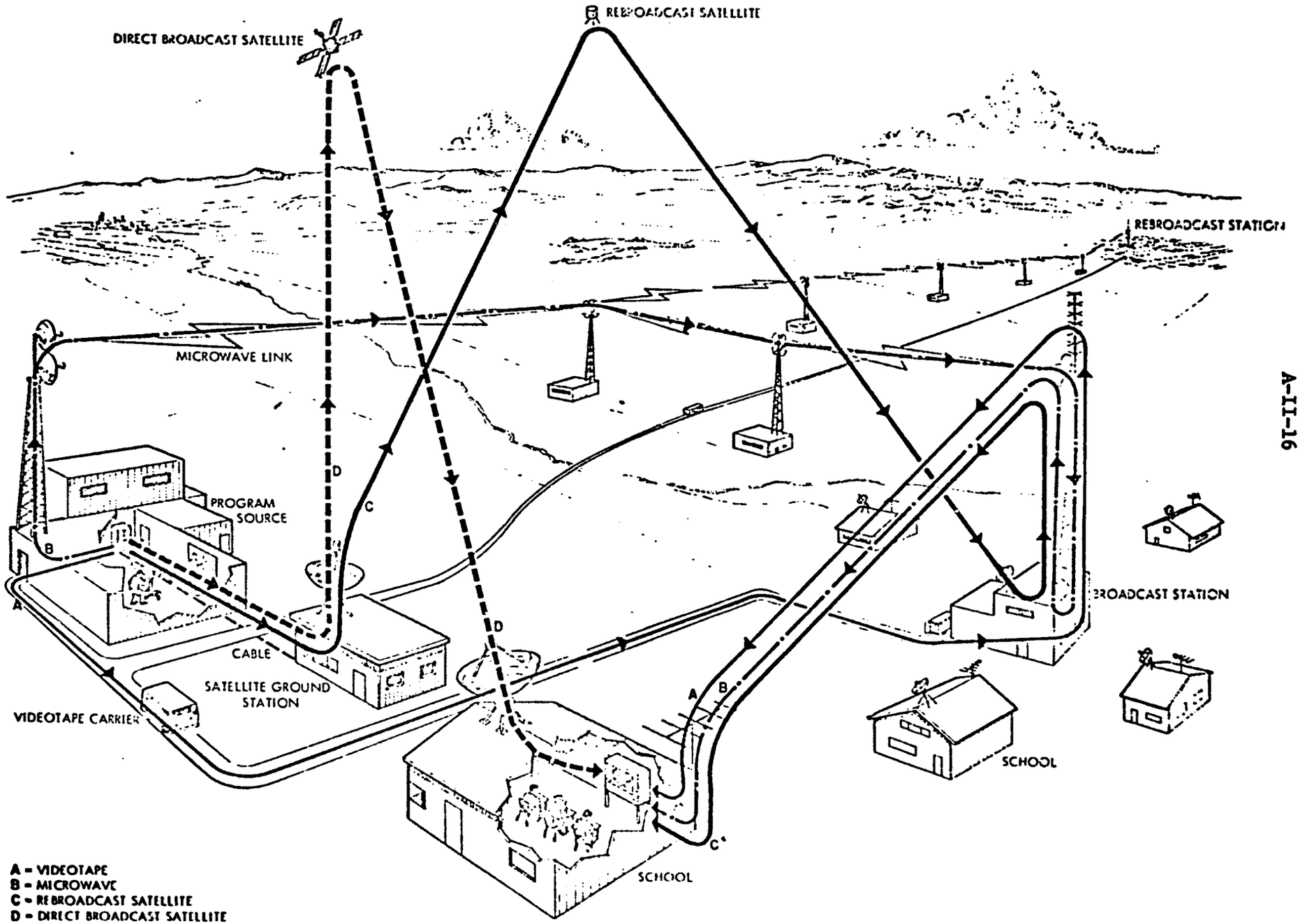

Table 2

RELATIVE PERFORMANCE OF ALTERNATIVE DISTRIBUTION SYSTEMS

Criterion	ETV Distribution System			
	Video Tape	Microwave	Rebroadcast Satellite	Direct Broadcast Satellite
Educational				
Ability to pace and control modernization	Poor	Good	Good	Excellent
Ability to reflect local programming needs	Excellent	Fair	Poor	Poor
Psychological impetus for modernization	Fair	Fair	Good	Excellent
Encouragement for multinational integration	Poor	Fair	Good	Excellent
Potential for growth in geographical coverage	Fair	Poor	Fair	Excellent
Simultaneous reception of important events	None	Good	Good	Excellent
Management				
Simplicity of local management	Poor	Fair	Fair	Good
Simplicity of central management	Good	Excellent	Fair	Fair
Adaptability to pilot tests of software	Excellent	Fair	Poor	Poor
Indirect Effects				
Spillover benefits for local communications	Good	Excellent	Good	Poor
Opportunity to develop local industries	Excellent	Good	Fair	Fair
Reliability				
Freedom from overall system interruption	Excellent	Good	Fair	Poor
Freedom from local failures	Poor	Fair	Fair	Good
Fiscal				
Cost of covering major urban centers	Excellent	Good	Fair	Poor
Cost of covering entire country	Fair	Poor	Poor	Good
Potential for major foreign assistance	Poor	Fair	Good	Good

signify the degree to which each system achieves the criterion noted. In the following paragraphs, the bases for the comparative ratings are discussed.

Ability to Pace and Control Modernization

ETV, however distributed, can be used as an instrument for reforming educational content and practices. Of the four alternative methods of distribution, those that are scheduled from the program source (for example, the nation's capital) provide more positive pacing and control than does the video tape distribution system, where the local television transmitting station broadcasts the program. Delays may occur in receiving tape from the program source. Some units of instruction may be omitted because local supervisors or teachers may be unfamiliar or insecure with the content. Thus, the video tape system does not offer pacing and control advantages inherent to the other distribution methods.

Of the centralized systems, the direct broadcast satellite was rated the highest on this criterion, because no administrative levels need intervene between program source and classroom.

Ability to Reflect Local Programming Needs

If local teachers are adequately prepared, a case can be made for allowing them flexibility in the pacing of instructional content. Here, the centralized distribution systems are at a disadvantage in relation to the video tape distribution made. The tape can be played at times most convenient to the majority of local teachers, and it can be replayed locally two or three times for remedial work or for students who missed the first showing. Of course, replay schedules are entirely possible with

the centralized systems too, but not with as great flexibility as for a locally scheduled station.

The microwave system has been given a slightly higher rating than the rebroadcast satellite, because the former has the potential to lead to the development of a more decentralized communications network and more nearly self-sufficient local television programming capability than the satellite-based system would. Television programming of local news or entertainment could be of assistance to local educational broadcasting.

Psychological Impetus for Modernization

The dramatic technology of satellite communication is more likely to capture the imagination of the people in a developing country and to implant the seeds of change than would the use of conventional technology. It can be speculated that the use of satellite technology could inspire teachers and students to make the needed break with traditional patterns. The direct broadcast satellite system was rated highest on this criterion, because the school's antennas would receive signals directly from the satellite instead of from an intermediary conventional television transmitter, thus heightening the sense of participating firsthand in advanced technology.

Encouragement for Multinational and Multicultural Integration

This criterion is related to the preceding one, in that the more localized systems of video tape or microwave distribution offer no technical imperatives for multinational or multicultural cooperation, whereas the wide coverage of satellite distribution systems requires at least technical and financial planning across national or cultural boundaries.

And technical and financial pooling may facilitate some sharing of educational content.

The four distribution systems can be rated on this criterion according to the degree to which each requires central pooling of programming efforts for economical and effective operations.

Potential for Growth in Geographical Coverage

On this criterion, the least satisfactory system is the microwave network, which requires the construction of expensive links whenever it is decided to extend the coverage. The video tape and rebroadcast systems are about equal on this count, requiring only that a new local television transmitter (or, for fringe areas, a signal booster) be established. The most flexible system, of course, is the direct broadcast satellite, where the signal can be brought into a school or a village located anywhere within the thousands-of-miles diameter coverage of the satellite, without waiting for the construction of intermediate transmitters. This capability alone has the potential to bring national coverage to rural and village populations years, perhaps decades, earlier than would be possible with alternative systems.

Simultaneous Reception of Live Events

The timeliness of live programs received simultaneously throughout a developing region is occasionally of importance in educational broadcasting and of great importance for news and political events in a general communication network. The video tape distribution system cannot offer any capability of this count, whereas the centralized systems can. The

direct broadcast satellite system was rated highest here, because simultaneous reception can be wherever receivers exist, whether or not a local television transmitter serves the area.

Simplicity of Local Management

Extensive video tape exchange represents a considerable local administrative burden. It is difficult to assure delivery of a large number of video tapes to subsidiary transmitting stations on time for use; yet if the time of delivery is set well in advance of use, the problems of storage and inventory are cumbersome. The local station must employ personnel who are skilled not only in inventory management and scheduling of these valuable tapes, but also in the operation and maintenance of a video tape recorder--valuable and sensitive equipment that must be carefully handled if it is to remain dependable and offer acceptable reception fidelity. Accordingly, the video tape system is rated the lowest on this criterion.

The centralized systems, where all scheduling is done at the source of programming, avoid the local administrative and logistical burden. On the other hand, both microwave and rebroadcast satellite systems require the management of local television broadcasting stations. Some specialized managerial and technical competence would be required.

The direct broadcast satellite system is rated highest of the four on this criterion, but even it requires operation and maintenance of a television receiver that has augmentation equipment necessary to receive and convert the signal directly from the satellite. Hence, it is given only a "good" rating.

Simplicity of Central Management

By this criterion, the satellite distribution systems, with their requirements for operating and maintaining complex earth stations and for keeping the satellite on station, rate lower than the terrestrial systems. Of the latter, the microwave network, once established, should be a good deal simpler to administer than the video tape exchange, which will require complex central and local management procedures for dispatching, receipt, storage, playing, replaying, and accounting for valuable video tape.

Adaptability to Pilot Tests of Software

Of the four systems, only that of video tape distribution lends itself easily to experimenting with educational braodcasting on a small scale at low cost to determine whether the technique offers important utility in comparisons with conventional instructional systems. The use of only one or two links in a microwave network could be considered a relatively modest pilot application, hence this system rates better than either of the satellite distribution methods. The satellite systems, with their enormous geographical coverage, tend to encourage all-or-none adoption, not pilot tests.

The above comments apply to situations in which the system is a single-purpose educational broadcasting system. If a telecommunications system, satellite or terrestrial, is available or is to be made available for other purposes, such as telephony or entertainment and news, it would be possible to conduct pilot tests of educational broadcasts on any of the four alternative distribution systems being compared. The organizers

of such pilot tests would not have to be concerned about the large unused geographical capacity of the satellite systems. They would, however, have to deal with a number of technical complexities associated with satellite communication that would not have to be faced in using more conventional terrestrial systems.

Spillover Benefits for Local Communications

In considering indirect effects, the ground-based systems offer greater spillover benefits in contributing to the growth of a communications infrastructure. The direct broadcast satellite is rated poor, because only the large and expensive transmitting ground station could be a source of broadcasting. In the other systems, local transmitters that would have alternative uses for local as well as central programming would be established.

Opportunity to Develop Local Industries

The satellite distribution systems include equipment of high technology that will probably continue to require foreign procurement. The terrestrially based systems, on the other hand, employ more nearly conventional technology. It can be expected that the electronics and construction industries of at least the larger developing countries like India, Brazil, and Mexico will continue to grow and will be able to account for an increasing share of initial and maintenance procurement of conventional telecommunications systems.

The video tape distribution system was rated the highest by this criterion, because it requires the most decentralized management. The

capability for managing this logistical system should have useful transfer to other local industrial management needs.

Any of the systems should encourage the building of a local or regional capability to manufacture receivers and service and maintain such equipment.

Freedom from Overall System Interruption

Satellite distribution systems are vulnerable to various kinds of interruption such as equipment faults at earth stations, drifting of the satellite off station, and satellite power failures. A satellite failure can result in the entire system being inoperable, which might pose severe readjustment strains on an educational system in which ETV had been integrated into curriculum. The direct broadcast satellite would be the most vulnerable to system failure, because no local television transmitters would be available for emergency programming of live or taped lessons.

Freedom from Local Failures

For the video tape system, which has the lowest rating on this criterion, the largest potential source of unreliability is the nonreceipt or misplacement of the particular video tape needed at a key time in the instructional sequence. The microwave and satellite distribution systems, where only one expert central crew controls the program scheduling, are less subject to local interruption than the video tape system, where less well-trained crews at each transmitting point increase the possibility of error. These systems are also subject to interruptions caused by failures of the local broadcasting station.

None of the television systems is rated higher than "good" on this criterion, because all are vulnerable to local power interruptions or voltage fluctuations--fairly common occurrences in developing countries.

Cost Comparisons

In Table 3, five alternative distribution systems for India are compared in terms of capital and operating costs. The system called "limited TV and local radio" was designed to cover 40 to 45 percent of India's population; the other four systems were designed to cover the 80 to 85 percent of population stated as a high priority objective by Indian leaders interviewed by the study team. Because Indian requirements call for a national television communication system with simultaneous reception, the alternative of video tape distribution is not included in the systems being compared. Of the systems studied, the direct broadcast satellite proved to be the least costly, followed by the combination of ground-based stations in the cities and direct satellite broadcasts to the villages.

The combined system seems particularly appropriate for helping to meet India's need for heterogeneity of language and cultural programming. The more local stations there are, the easier it will be to produce programs for specialized local needs. At the same time, the direct broadcast satellite can be a means of bringing television to the large number of remote villages decades sooner than would be possible with only a ground-based system.

It is not easy for anyone except the purchaser to say when a cost is too great, but costs of the combination system for India were compared

Table 3

FIVE TV DISTRIBUTION SYSTEMS FOR INDIA:
TOTAL CAPITAL AND OPERATING COSTS OVER 20 YEARS
AND AVERAGE COST PER YEAR
(Millions of Dollars)

System	Capital Costs		Operating Costs		Capital and Operating Costs	
	Total	Annual Average	Total	Annual Average	Total	Annual Average
Limited TV and local radio	$169.3	$ 8.5	$155.2	$ 7.5	$324.5	$16.0
Ground-based TV	442.4	22.1	313.4	15.7	755.8	37.8
Direct broadcast satellite	433.4	21.7	202.7	10.1	636.1	31.8
Rebroadcast satellite	456.5	22.8	266.3	13.3	722.8	36.1
Ground-based and direct broadcast satellite	436.5	21.8	240.9	12.9	677.4	33.8

with certain economic indicators. As Table 4 demonstrates, the annual cost, capital plus operating, is never likely to be much greater than 1 percent of the annual expenditure on education, or .07 of 1 percent of the national income.

With respect to the composition of expenditures on any of the proposed systems for India,analysis shows that the largest portion is spent on receivers--purchase, maintenance, and replacement. In the direct broadcast satellite system, for example, receivers represent about 75 percent of capital cost, satellites themselves only about 11 percent. Even in ground-based television, receivers represent about 50 percent of capital investment.

Table 5 presents the initial and operating costs of four alternative distribution systems designed to meet an estimate of Latin America's 1980 demand for ETV. As shown by the total costs for each of the three regions making up Latin America, the video tape system shows the lowest initial and operating costs, and the direct broadcast satellite system shows the highest costs. Microwave transmission and the rebroadcast satellite systems provide fairly interchangeable service. Where microwave networks are expected to be available, this system shows the lower cost of the two; where terrain and jungle are expected to delay the construction of microwave links, as in Peru, Bolivia, and Brazil, the rebroadcast satellite system shows lower costs.

The demand estimate on which Table 5 was based was primarily an urban demand, in which television service was extended in descending order of student concentrations. To test the effect of providing more nearly

Table 4

COMPARISONS OF ANNUAL COSTS OF A COMBINATION SATELLITE AND GROUND-BASED SYSTEM WITH ECONOMIC INDICATORS FOR INDIA, AT FIVE-YEAR INTERVALS

	1970-71	1975-76	1980-81	1985-86
National income (billions of dollars)	$37.5	$50.1	$67.1	$89.7
National expenditure on education (billions of dollars)	$1.3	$2.1	$3.3	$5.3
Annual cost of establishing and operating national television (billions of dollars)	$.0046	$.0193	$.046	$.0656
Education expenditure ÷ national income (percent)	3.4%	4.1%	5.0%	6.0%
Cost of national television ÷ national income (percent)	.012%	.039%	.069%	.073%
Cost of national television ÷ education expenditure (percent)	.35%	.91%	1.4%	1.2%

Table 5

LATIN AMERICAN ETV DISTRIBUTION SYSTEMS COSTS, 1980
(Thousands of Dollars)

Served by One Satellite of 12 Video Channels

Line	Cost Element	Central America A Video Tape	Central America B Micro-wave	Central America C Rebroad-cast	Central America D Direct Broadcast	Mexico A Video Tape	Mexico B Micro-wave	Mexico C Rebroad-cast	Mexico D Direct Broadcast	Colombia A Video Tape	Colombia B Micro-wave	Colombia C Rebroad-cast	Colombia I Direct Broadcast
	Initial Costs:												
1.	Broadcast stations total	$ 8,031	$ 8,031	$ 8,031	$ n.a.	$ 8,616	$ 8,616	$ 8,616	$ n.a.	$ 9,273	$ 9,273	$ 9,273	$ n.a.
2.	Broadcast stations, main	n.a.	n.a.	n.a.	8,031	n.a.	n.a.	n.a.	2,680	n.a.	n.a.	n.a.	1,752
3.	Microwave	n.a.	2,669	n.a.	n.a.	n.a.	3,149	n.a.	n.a.	n.a.	3,089	n.a.	n.a.
4.	Satellite and launch I	n.a.	n.a.	3,000	7,850	n.a.	n.a.	3,060	7,970	n.a.	n.a.	3,480	9,080
5.	Satellite and launch II	n.a.	n.a.	n.a.	6,050	n.a.	n.a.	n.a.	6,130	n.a.	n.a.	n.a.	7,020
6.	Ground stations, transmitting	n.a.	n.a.	3,810	3,810	n.a.	n.a.	1,280	1,280	n.a.	n.a.	640	640
7.	Ground stations, receiving	n.a.	n.a.	0	n.a.	n.a.	n.a.	3,192	n.a.	n.a.	n.a.	2,660	n.a.
8.	Tape library - total	173	n.a.	n.a.	n.a.	160	n.a.	n.a.	n.a.	384	n.a.	n.a.	n.a.
9.	Tape library - main	n.a.	410	410	410	n.a.	436	436	436	n.a.	248	248	218
10.	Studios and equipment	800	800	800	800	1,067	1,067	1,067	1,067	1,334	1,334	1,334	1,334
11.	Receivers	1,890	1,890	1,890	1,890	1,350	1,350	1,350	1,350	3,340	3,340	3,340	3,340
12.	Additions to receivers I	n.a.	n.a.	n.a.	10,690	n.a.	n.a.	n.a.	7,620	n.a.	n.a.	n.a.	18,900
13.	Additions to receivers II	n.a.	n.a.	n.a.	6,600	n.a.	n.a.	n.a.	4,708	n.a.	n.a.	n.a.	11,680
14.	Total I	$11,199	$13,803	$17,971	$33,514	$11,523	$14,618	$19,031	$22,403	$14,331	$17,284	$20,975	$35,291
15.	Total II	$ n.a.	$ n.a.	$ n.a.	$28,188	$ n.a.	$ n.a.	$ n.a.	$17,651	$ n.a.	$ n.a.	$ n.a.	$26,014
	Operating Costs:												
16.	Broadcast station	1,200	1,200	1,200	1,200	1,600	1,600	1,600	400	1,200	1,200	1,200	200
17.	Microwave	n.a.	100	n.a.	n.a.	n.a.	117	n.a.	n.a.	n.a.	431	n.a.	n.a.
18.	Satellite and launch-II	n.a.	n.a.	625	1,370	n.a.	n.a.	650	1,410	n.a.	n.a.	725	1,390
19.	Ground station	n.a.	n.a.	356	210	n.a.	n.a.	474	80	n.a.	n.a.	356	40
20.	Tape transport	7	n.a.	n.a.	n.a.	6	n.a.	n.a.	n.a.	4	n.a.	n.a.	n.a.
21.	Tape library	35	6	6	6	41	6	6	6	35	6	6	6
22.	Program production, teacher training set maintenance	1,450	1,450	1,450	1,450	1,580	1,580	1,580	1,580	2,236	2,236	2,236	2,236
23.	Maintenance of receiver additions	n.a.	n.a.	n.a.	468	n.a.	n.a.	n.a.	336	n.a.	n.a.	n.a.	830
24.	Total	$ 2,692	$ 3,056	$ 3,637	$ 4,734	$ 3,227	$ 3,603	$ 4,310	$ 3,812	$ 3,475	$ 3,873	$ 4,523	$ 4,902

Note: n.a. = not applicable.

Venezuela				Total				Served by One Satellite: Brazil			
A Video Tape	B Micro-wave	C Rebroad-cast	D Direct Broadcast	A Video Tape	B Micro-wave	C Rebroad-cast	D Direct Broadcast	A Video Tape	B Micro-wave	C Rebroad-cast	D Direct Broadcast
$6,894	$ 6,894	$ 6,894	$ n.a.	$32,847	$32,847	$32,847	$ n.a.	$12,382	$12,382	$12,382	$ n.a.
n.a.	n.a.	n.a.	1,339	n.a.	n.a.	n.a.	13,805	n.a.	n.a.	n.a.	4,130
n.a.	3,909	n.a.	n.a.	n.a.	12,816	n.a.	n.a.	n.a.	24,228	n.a.	n.a.
n.a.	n.a.	2,923	7,600	n.a.	n.a.	12,460	32,500	n.a.	n.a.	12,148	16,750
n.a.	n.a.	n.a.	3,900	n.a.	n.a.	n.a.	25,100	n.a.	n.a.	n.a.	n.a.
n.a.	n.a.	643	610	n.a.	n.a.	6,400	6,100	n.a.	n.a.	1,820	1,820
n.a.	n.a.	3,148	n.a.	n.a.	n.a.	9,044	n.a.	n.a.	n.a.	5,320	n.a.
385	n.a.	n.a.	n.a.	1,704	n.a.	n.a.	n.a.	574	n.a.	n.a.	n.a.
n.a.	208	204	208	n.a.	1,302	1,302	1,302	n.a.	260	260	260
534	534	534	534	3,735	3,735	3,735	3,735	1,067	1,067	1,067	1,067
1,910	1,910	1,910	1,910	8,190	8,190	8,490	8,190	3,150	3,150	3,150	3,150
n.a.	n.a.	n.a.	10,810	n.a.	n.a.	n.a.	48,020	n.a.	n.a.	n.a.	21,200
n.a.	n.a.	n.a.	6,685	n.a.	n.a.	n.a.	29,673	n.a.	n.a.	n.a.	11,000
$9,723	$13,455	$16,238	$23,011	$16,776	$59,190	$74,278	$114,252	$17,173	$41,087	$36,147	$48,677
$ n.a.	$ n.a.	$ n.a.	$17,216	$ n.a.	$ n.a.	$ n.a.	$ 89,369	$ n.a.	$ n.a.	$ n.a.	$38,477
1,400	1,400	1,490	200	5,400	5,400	5,400	2,000	2,600	2,600	2,600	600
n.a.	541	n.a.	n.a.	n.a.	1,789	n.a.	n.a.	n.a.	3,521	n.a.	n.a.
n.a.	n.a.	600	1,300	n.a.	n.a.	2,600	5,670	n.a.	n.a.	2,600	4,280
n.a.	n.a.	415	40	n.a.	n.a.	1,600	400	n.a.	n.a.	700	200
4	n.a.	n.a.	n.a.	21	n.a.	n.a.	n.a.	17	n.a.	n.a.	n.a.
35	6	9	6	146	18	18	18	76	6	6	6
1,513	1,513	1,513	1,513	6,779	6,779	6,779	6,779	2,904	2,904	2,900	2,904
n.a.	n.a.	n.a.	475	n.a.	n.a.	n.a.	2,100	n.a.	n.a.	n.a.	700
$ 2,948	$ 4,860	$ 3,934	$ 3,534	$12,346	$13,986	$16,397	$ 16,967	$ 5,597	$ 9,031	$ 8,806	$ 8,690

Line	Cost Element	Argentina A Video Tape	Argentina B Micro-wave	Argentina C Rebroad-cast	Argentina D Direct Broadcast	Bolivia A Video Tape	Bolivia B Micro-wave	Bolivia C Rebroad-cast	Bolivia D Direct Broadcast
	Initial Costs:								
1.	Broadcast stations total	$ 9,059	$ 9,059	$ 9,059	$ n.a.	$3,651	$ 3,651	$ 3,651	$ n.a.
2.	Broadcast stations, main	n.a.	n.a.	n.a.	1,339	n.a.	n.a.	n.a.	928
3.	Microwave	n.a.	16,300	n.a.	n.a.	n.a.	6,619	n.a.	n.a.
4.	Satellite and launch I	n.a.	n.a.	3,131	1,218	n.a.	n.a.	1,989	2,677
5.	Satellite and launch II	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.
6.	Ground stations, transmitting	n.a.	n.a.	640	640	n.a.	n.a.	610	610
7.	Ground stations, receiving	n.a.	n.a.	1,230	n.a.	n.a.	n.a.	2,660	n.a.
8.	Tape library - total	579	n.a.	n.a.	n.a.	217	n.a.	n.a.	n.a.
9.	Tape library - main	n.a.	206	206	206	n.a.	132	132	132
10.	Studios and equipment	800	800	800	800	531	531	531	531
11.	Receivers	772	772	772	772	218	218	218	218
12.	Additions to receivers I	n.a.	n.a.	n.a.	7,726	n.a.	n.a.	n.a.	2,184
13.	Additions to receivers II	n.a.	n.a.	n.a.	2,700	n.a.	n.a.	n.a.	760
14.	Total I	$11,210	$26,146	$18,867	$15,701	$4,650	$11,154	$ 9,824	$ 7,311
15.	Total II	$ n.a.	$ n.a.	$ n.a.	$10,675	$ n.a.	$ n.a.	$ n.a.	$ 5,887
	Operating Costs:								
16.	Broadcast station	1,800	1,800	1,800	200	1,200	1,200	1,200	200
17.	Microwave	n.a.	2,369	n.a.	n.a.	n.a.	915	n.a.	n.a.
18.	Satellite and launch	n.a.	n.a.	600	1,080	n.a.	n.a.	430	600
19.	Ground station	n.a.	n.a.	320	60	n.a.	n.a.	350	60
20	Tape transport	9	n.a.	n.a.	n.a.	3	n.a.	n.a.	n.a.
21.	Tape library	53	6	6	6	35	6	6	6
22.	Program production, teacher training, set maintenance	1,218	1,246	1,216	1,216	698	698	698	698
23.	Maintenance of receiver additions	n.a.	n.a.	n.a.	177	n.a.	n.a.	n.a.	50
24.	Total	$ 3,108	$ 5,421	$ 4,232	$ 2,769	$1,936	$ 2,869	$ 2,684	$ 1,704

Note: n.a. = not applicable.

Table 5 (concluded)

Served by One Satellite of 12 Video Channels

Chile				Peru				Uruguay				Total			
A Video Tape	B Micro-wave	C Rebroad-cast	D Direct Broadcast	A Video Tape	B Micro-wave	C Rebroad-cast	D Direct Broadcast	A Video Tape	B Micro-wave	C Rebroad-cast	D Direct Broadcast	A Video Tape	B Micro-wave	C Rebroad-cast	D Direct Broadcast
$6,445	$ 6,445	$ 6,445	$ n.a.	$ 7,949	$ 7,949	$7,949	$ n.a.	$1,852	$1,852	$ 1,852	$ n.a.	$28,956	$28,956	$28,956	$ n.a.
n.a.	n.a.	n.a.	1,339	n.a.	n.a.	n.a.	1,339	n.a.	n.a.	n.a.	926	n.a.	n.a.	n.a.	5,869
n.a.	4,350	n.a.	n.a.	n.a.	18,270	n.a.	n.a.	n.a.	630	n.a.	n.a.	n.a.	44,178	n.a.	n.a.
n.a.	n.a.	2,742	3,690	n.a.	n.a.	2,290	3,082	n.a.	n.a.	2,290	3,082	n.a.	n.a.	12,445	16,749
n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.
n.a.	n.a.	640	640	n.a.	n.a.	640	640	n.a.	n.a.	640	640	n.a.	n.a.	3,200	3,200
n.a.	n.a.	2,660	n.a.	n.a.	n.a.	3,724	n.a.	n.a.	n.a.	532	n.a.	n.a.	n.a.	13,832	n.a.
272	n.a.	n.a.	n.a.	418	n.a.	n.a.	n.a.	195	n.a.	n.a.	n.a.	1,711	n.a.	n.a.	n.a.
n.a.	180	180	180	n.a.	152	152	152	n.a.	151	151	151	n.a.	821	821	821
800	800	800	800	534	534	534	534	534	534	534	534	3,202	3,202	3,202	3,202
920	920	920	920	1,410	1,410	1,410	1,410	164	164	164	164	3,484	3,484	3,484	3,484
n.a.	n.a.	n.a.	9,200	n.a.	n.a.	n.a.	14,112	n.a.	n.a.	n.a.	1,644	n.a.	n.a.	n.a.	34,696
n.a.	n.a.	n.a.	3,202	n.a.	n.a.	n.a.	4,925	n.a.	n.a.	n.a.	573	n.a.	n.a.	n.a.	12,160
$8,437	$12,695	$14,387	$16,759	$10,311	$28,315	$16,699	$21,299	$2,745	$3,331	$ 6,163	$ 7,141	$37,353	$80,611	$62,840	$68,221
$ n.a.	$ n.a.	$ n.a.	$10,771	$ n.a.	$ n.a.	$ n.a.	$12,082	$ n.a.	$ n.a.	$ n.a.	$ 6,070	$ n.a.	$ n.a.	$ n.a.	$45,185
1,200	1,200	1,200	200	1,600	1,600	1,600	200	400	400	400	200	6,200	6,200	6,200	1,000
n.a.	557	n.a.	n.a.	n.a.	2,417	n.a.	n.a.	n.a.	17	n.a.	n.a.	n.a.	6,325	n.a.	n.a.
n.a.	n.a.	570	950	n.a.	n.a.	470	760	n.a.	n.a.	470	780	n.a.	n.a.	2,600	4,280
n.a.	n.a.	350	60	n.a.	n.a.	465	60	n.a.	n.a.	116	60	n.a.	n.a.	1,800	300
7	n.a.	n.a.	n.a.	7	n.a.	n.a.	n.a.	1	n.a.	n.a.	n.a.	27	n.a.	n.a.	n.a.
29	6	6	6	47	6	6	6	12	6	6	6	176	30	30	30
975	975	975	975	1,021	1,021	1,021	1,021	771	771	771	771	4,711	4,711	4,711	4,711
n.a.	n.a.	n.a.	211	n.a.	n.a.	n.a.	324	n.a.	n.a.	n.a.	38	n.a.	n.a.	n.a.	800
$2,211	$ 2,738	$ 3,101	$ 2,402	$ 2,675	$ 5,014	$ 3,562	$ 2,391	$1,184	$1,194	$ 1,763	$ 1,858	$11,114	$17,266	$15,341	$11,121

total national coverage, a special study was made of one country, Colombia, using a higher demand estimate for 1980, in which all Colombian cities and towns of over 10,000 population would be reached. Costs were recalculated for the video tape and the direct broadcast satellite distribution systems. Total initial costs for Colombia became $30 million for the video tape system, versus $28 million for the direct broadcast satellite system. The direct broadcast satellite thus replaces the video tape system as the least expensive system, largely because the cost of procuring television sets augmented to receive the satellite signal becomes less than the cost of constructing local television transmitters that reach relatively few students. The direct broadcast satellite system also showed lowest operating costs for the assumption of full national coverage of Colombia.

Table 6 presents the initial and operating costs of two methods of meeting the projected 1980 ETV demand for the countries studied in Latin America. To simplify the table, only the direct broadcast satellite and video tape systems were compared. Examination of the dollar cost columns shows that the satellite system makes initial and operating cost savings in broadcast stations, but that these are more than offset by costs of satellite and launch and of the television set augmentations required to receive the signal directly from the satellite. The cost of set augmentations is highly sensitive to quantity procured. If substantially more than the 75,000 sets on which this calculation was based were to be procured, this initial cost element would be considerably reduced.

The percentage distribution column in Table 6 is informative on how funds would have to be spent for either distribution system. In the video tape system, the bulk of initial expenditures is on broadcast stations

Table 6

COSTS OF TWO ETV
DISTRIBUTION SYSTEMS TO MEET 1980 DEMAND:
LATIN AMERICAN TOTALS AND PERCENT DISTRIBUTION BY COST ELEMENT

	Video Tape System		Direct Broadcast Satellite System	
	$000	%	$000	%
Initial Costs				
Broadcast stations	$ 74,185	73.2%	$ 24,104	14.1%
Satellite and launch	n.a.	n.a.	58,600	33.9
Ground stations	n.a.	n.a.	11,420	6.6
Tape library	3,989	3.9	2,383	1.4
Studios and equipment	8,004	7.9	8,004	4.7
Receivers	15,124	15.0	15,124	8.8
Additions to receivers	n.a.	n.a.	52,833	30.5
Total	$101,302	100.0%	$172,468	100.0%
Operating Costs (Annual)				
Broadcast stations	$ 14,200	48.9%	$ 3,600	9.8%
Satellite and launch	n.a.	n.a.	14,230	38.7
Ground stations	n.a.	n.a.	900	2.4
Tape transport	65	0.2	n.a.	n.a.
Tape library	398	1.4	54	0.1
Program production, teacher training, and set maintenance	14,394	49.5	14,394	39.2
Maintenance of receiver additions	n.a.	n.a.	3,600	9.8
Total	$ 29,057	100.0%	$ 36,778	100.0%

Note: n.a. = not applicable.

and studios and their equipment, whereas in the direct broadcast satellite system, the largest items are for the satellite and launch and for procuring set augmentations. With respect to operating costs, the items of program production, teacher training, and set maintenance are important for both distribution systems, but in the satellite system operating funds must be set aside for successive launches every three to five years to maintain the communications capability.

The quantity of sets to be procured was almost a million in India and less than 100,000 in Latin America. Aside from the differences in the size of populations to be served, this is because only 6,000 sets are in use in India, while six million are already in use in Latin America. The difference in procurements explains much of the variation in percentage distributions of costs for the two case regions.

The following conclusions can be drawn from the several analyses made for India and Latin America:

- Video tape distribution is the least-cost system up to a high degree of saturation of urban schools.
- The direct broadcast satellite system becomes the least-cost system for population residing beyond the range of transmitters located in principal cities.
- If ETV is extended to student populations in ascending order of cost per student served, the breakeven point at which the direct broadcast satellite begins to be more cost-effective than video tape distribution lies between 35 and 60 percent of total country population, the particular point being

dependent on population distribution and the presence or absence of television transmitters in outlying areas.

- Of the four distribution systems, only the direct broadcast satellite system exhibits declining unit cost per student served with increasing coverage. The other systems exhibit rising unit costs after the population residing in large and medium-sized cities and other densely populated areas has been served.

Potential for Major Foreign Assistance

With the predisposition of multilateral and bilateral donors to favor large scale technologically based assistance programs, it would appear that the satellite distribution systems might have somewhat better prospects of attracting assistance grants or loans than would the more conventional distribution systems.

A NOTE TO PROSPECTIVE USER COUNTRIES

On the basis of these studies, the research team prepared suggestions for officials of countries or regions who are considering a major expansion of television, with or without satellites, for education and development. Briefly, the following procedure would seem advisable:

- Begin with needs, rather than with technology. The important question is whether the need to expand or upgrade instruction and information is sufficient to justify a major system development. The system should grow out of the priority needs and be tailored to meet them.
- Begin with television, rather than with satellites. The question is, can television make a significant contribution to the country's educational and development needs?
- If so, compare different systems for delivering television. Develop these systems in some detail, including some sample programming, a phasing of expansion, and an inventory of the economic, human, and technical resources that would be required. In particular, do not forget to look at systems that combine more than one method of delivery--especially the combination of ground-based and satellite television.
- Study the heterogeneity problem carefully. How can the system best be designed to meet both regional and local needs? Here, combined systems may prove especially attractive.

- Survey the resources. What will be required for development of an electronics industry, engineering and technical personnel, broadcasting personnel, extension of electric power, transportation, and teacher training? If these are not available in sufficient quantities, how can they be provided?

- Try to solve, at the beginning, the problem of organization and control. This is discussed at some length in the India case study, and it has proved to be a serious problem in numerous countries. Briefly, a major television system, with thousands of employees, requires both freedom to be creative and close contact with the substantive agencies that should participate. What is the best assignment of organizational responsibilities for these two purposes, and how should the assignment relate to the control system of government?

- Plan, if possible, a gradual expansion of the system, one step at a time. If the job is to be done thoroughly, a period of several years will be needed for: detailed planning; hiring and training; manufacture of receivers and other electronic gear; construction of stations; work on content and curriculum, scheduling, making, and testing of programs; and practice in using the new system. If time is allowed for these tasks, there will be fewer problems, fewer mistakes in the first years, and less chance for a failure. If the development is gradual and measured, the cost can be spread out more evenly, the experience and skills gained in early stages can be utilized in later stages, mistakes can be corrected, and formidable problems can be mastered before they affect an entire

system. Ideally, the plan should be developed so that at any given stage it is possible to take stock and decide on the next step.

POLICY IMPLICATIONS FOR THE UNITED STATES

No intimate knowledge was available to the study teams regarding policy issues the United States government faces in satellite communication and in development assistance for India and Latin America. Nevertheless, on the basis of the case studies, the following suggestions are offered:

- Conserve resources vital to satellite communication systems. A need for three satellites, each with 12 video channels, has been projected to meet the 1980 educational requirements of Latin American countries. These would be in addition to the INTELSAT requirements for an Atlantic service, the domestic satellite needs of the United States (perhaps four satellites), the domestic satellite needs of Canada (now estimated at three satellites), and military needs. The estimate of one satellite for India is more modest and, indeed, may be too modest.

  Planning for satellite communications calls attention to the limited availability of frequency spectrum and of "parking slots" in space for synchronous satellites. These are world resources, and it is hoped that the policy of the United States government will be to conserve the necessary part of such resources for human resources development. International reallocation of frequencies and a basic scheme for assigning satellite "parking slots" may be required.

- Build competence in educational and developmental television. Television for human resources development will be as effective as the kind of resources--human, technical, and economic--that are put into it. High priority should be given requests for assistance in training and retraining of teachers, broadcasters, planners, and development personnel to become familiar with and skilled in the use of television for education and development. Most of such training, of course, need not and should not be given in the United States. It should be the policy of the United States to support a limited number of excellent demonstration projects in the use of television. A project such as the program now being instituted by the government of El Salvador, with U.S. assistance, can do more to advance the potential of human resources television than a number of instances of small support to less well-planned projects. Finally, existing U.S. policy to support regional integration and cooperation in education is of great importance in making feasible the cooperative use of human resources television, whether terrestrial or by satellite. Examples of points of leverage for this purpose in Latin America are programs for intercountry harmonizing of curriculum and textbooks, implementation of the planned OAS training center in ETV, and exchange of educators and broadcasters.

- Give priority to requests from developing countries for assistance in training and retraining teachers to become effective in an instructional system of which ETV is an integral part. As an example, the training technique of microteaching is useful in

meeting the dual objectives of modernizing pedagogy and orienting teachers to the power of the television medium.

- Build from strength. The aid policy of the United States in the area of developmental television and satellite educational systems should make maximum use of the extraordinary experience and resources of the United States in such areas as instructional broadcasting, space science, development planning, and social research. Much training might well be built around relatively successful projects, such as that in Samoa, Colombia, and El Salvador, all accomplished with U.S. assistance. The experience of developing regions with these new technologies should be studied carefully and reported widely, on film and on paper. In the United States, there has been probably more experience with video tape exchange (which is treated at length as an element of Latin American systems) than anywhere else in the world. Microteaching, one of the most promising devices for training teachers, has been developed here. And much of the work on communications satellites has been done here. It is worth considering what sorts of centers or other organizations in this country or elsewhere might best make some of these resources available where they can do the most good in human resources development.

- Plan software for ETV systems. One of the greatest bottlenecks in developing satellite-based television systems is likely to be the absence of planning for the software needs of these systems. In Latin America, it was necessary for the project team to make the

demand estimates included in this report with entirely insufficient information, because projections by Latin Americans had not been made. Despite India's long tradition of planning, there was very little in existence that could be put immediately to use if the country were to decide to take up a satellite-distribution system. The important step in planning at this moment is not to repeat hardware-oriented planning studies that make gross and unwarranted assumptions about educational applications, but rather to look critically and in detail at possible educational and developmental applications of the broadcast media. Therefore, the policy of the United States should be to look favorably on requests for assistance in planning and organizing the software aspects of satellite systems.

- Encourage pilot projects. The proposed cooperation between NASA and INCOSPAR in arranging for a satellite to be made available to India for a limited period of experimentation will be useful in working out some of the hardware, maintenance, programming, and administrative questions of satellite broadcasting. This cooperation will be generally stimulating to plans for satellite systems. It seems that there is good reason for other pilot projects, especially in regions where there is a good chance of developing major satellite television systems for human resources development. For example, if it were possible to obtain another satellite under similar arrangements, particularly one having rudimentary direct broadcast capability, it might be beneficial to offer Latin Americans the chance to try it out for a time. The terms of the

offer should include provision for multinational cooperation and for Latin American countries to plan and manage the program. Needless to say, assistance and advice should be made available to such projects so that as much as possible can be learned from them and these lessons can be made widely known.

Support research on critical problems influencing effectiveness and cost. Considering the probable usefulness of direct broadcast satellites and their interesting growth potential for large scale coverage, it would be useful to direct some research toward minimizing the system cost represented by the necessary augmentation of receivers for direct reception--that is, the antenna, pre-amplifier, and feed--particularly for production in quantities between 10,000 and 200,000.

APPENDIX III

Costs of Educational Media Systems

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INTRODUCTION

In view of the national goal to provide every citizen the opportunity for quality education to the level of his desire and ability, the educator is confronted with the task of providing each student with the best education possible within the bounds of available funds, personnel, and facilities. Educational media systems may be a valuable source of help in the accomplishment of this task. Because of the lack of sufficient data, the selection of the best medium for presentation of a particular instructional unit usually is based on a subjective evaluation of effectiveness and a superficial estimate of cost.

The purpose of this study was to investigate the cost of instructional media systems. The first objective was to provide the educator with a set of guidelines for realistically estimating the total cost of such systems. To gain this objective it was necessary first to identify and investigate a set of commonly used or proposed media systems and to develop a methodology for determining total system costs.

The data collected and analyzed during the study achieved the second objective of providing a data base for use by researchers in further studies relating to the selection, implementation, and operation of instructional media systems. A final objective of the study was to present recommendations which can result in cost savings when media systems are used. The recommendations are in the areas of media utilization, application of new technology, and educational system organization....

SELECTION OF A MEDIA SYSTEM--AN OVERVIEW

Estimating the costs of purchasing, installing, implementing, and operating a media system is not an isolated activity. Rather, it is part of the broader overall process of media system selection.

Cost estimation, the subject of this study, must be preceded--and followed--by certain other necessary activities to insure optimum results from the use of a media system. These activities, while outside the scope of this study, are examined briefly here to show their relation to cost estimation.

The major steps in media system selection appear graphically in Fig. 1. Although the component activities are presented and discussed sequentially, it should be emphasized that the steps in media selection are interactive.

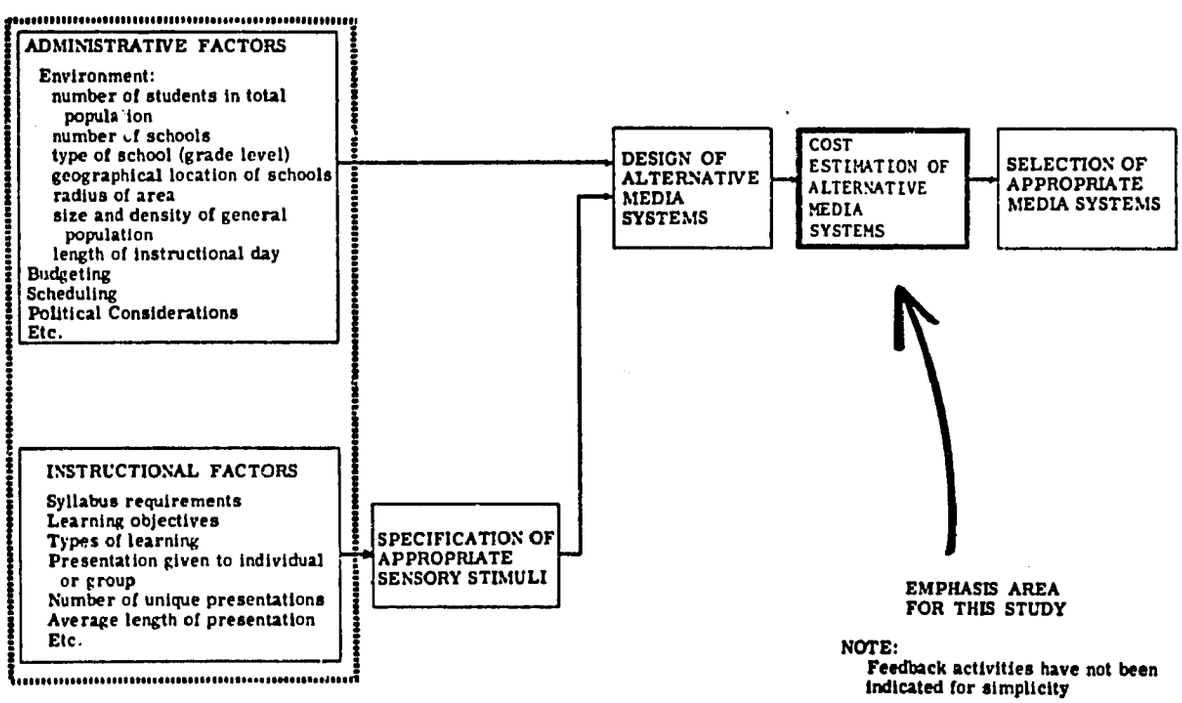

Figure 1. Selection of a Media System--An Overview

The results of an activity or activities in one step may not only provide data for a subsequent activity, but may also modify activities that have gone before.

The selection process begins with an examination of the educational setting in which the chosen media system is to function. Most educators agree that this setting consists mainly of an administrative component and an instructional component. Each component contains limiting factors which shape the specific data used in later stages of the selection process, namely specification of appropriate sensory stimuli, design of alternative media systems, cost estimation of the alternative systems, and ultimately, selection of the appropriate system.

Final selection of a media system is followed by the customary procedures of contract specification, review of bids, and award of a contract for equipment and installation. Two other "post selection" activities are essential at this point--implementation (training and operation) and evaluation. Logically, planning for these activities should be completed well before this time. Some of the ground work should already have been laid at earlier stages of the selection process. Staff acceptance of new media is more likely if teachers have participated in the selection process and have received instruction in how the new media are to be used. Operating procedures which allow for a period of adjustment must be carefully planned and introduced.

Fig. 2 illustrates the sequence of general steps taken to determine the cost of a media system. Blocks 1 and 2 produce the media system characteristics which determine the system's configuration. Blocks 3, 4, and 5

develop the costs in each of the three divisions into which the system has been separated. Block 6 sums up all costs prior to the selection decision that is made in Block 7. Actually, decisions are made throughout the entire process and some systems may be rejected or modified well before Block 7 is reached.

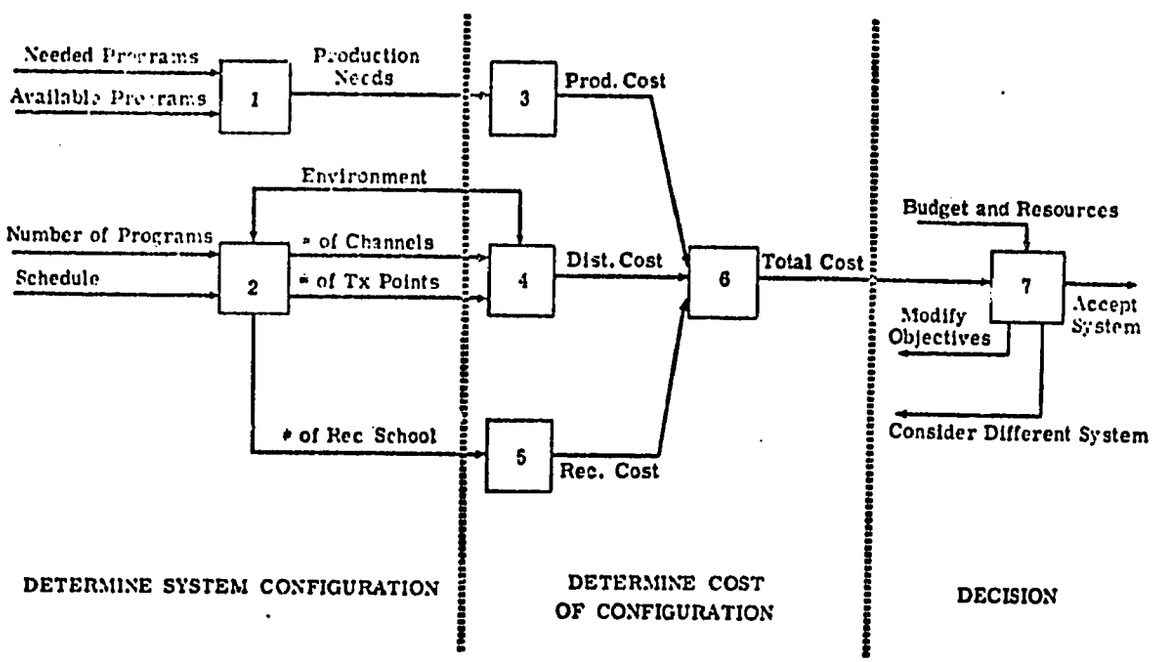

Figure 2. Cost Determinations

METHODOLOGY

The method of the study involves the specification of a task and an environment. The task describes "what the system is doing" and the environment describes "over what area and for how many people it is doing it." A valid comparison of media systems can be made only when a single real environment and the actual educational task are specified in detail for each case under study. To attempt this type of approach would mean the illustration of hundreds of cases consisting of different systems and their variations applied to many educational tasks over many different environments. This mounumental effort would still involve some generalizations and assumptions and would only produce a larger group of system costs which might result in more confusion than clarification.

Therefore, we have chosen a general expression for the task and a small number of generalized environments to construct a framework for media costs. Hopefully, this method may reduce the errors in system comparisons. It will not eliminate them. Where a media system does not fit a portion of the model at all, it will be so indicated. Where a media system does not fit a portion of the model as well as another system, it will be costed and explanatory notes appended (in the full original report) to describe the problem.

Environments Defined

Each media system is costed with respect to a number of environments. The environments are to a great extent hypothetical. However, they are models which were created after examining actual data. In particular,

city and metropolitan area descriptions closely resemble the city of Washington, D.C. and its environs. The geographical areas and population densities of the other environments are similar to those found in section of the United States.

Local District Model: The smallest environment is the school district which may vary in size from a few hundred to over a million students. The size chosen for this study was 15,000 elementary and secondary students in an area of approximately 80 square miles. Although the majority of school districts in the United States are much smaller, those with 3,000 or 4,000 students will not have the distribution problems which become extremely important in larger systems. Also, some of the media systems are too expensive (even in their smallest configuration) to be supported by a small district. However, if these smaller administrative units join together in a cooperative effort of about 15,000 students, the costs can be apportioned on a per pupil rate for each unit.

The school district used as the model consists of 14 elementary schools and four secondary schools. The elementary schools are a combination of K-6 and K-8 configurations, and the secondary schools include junior, senior, and possibly a vocational high school. For the purpose of this study, an elementary school will have an average of about 600 students; a secondary school will have an average of about 1,400 students. (The student population in each environment [local, city, state, etc.] has been rounded off to form convenient numbers; as a result the number of students per school when multiplied by the number of schools will not produce the exact student population indicated.) The school district is irregular in shape, but all the schools are within a circle whose radius is six miles.

City Model: The city covers an area of 70 miles and has a total population of about 800,000 with approximately 11,500 people per square mile. The shape of the city is roughly rectangular and the entire area can be encompassed by a six mile radius circle. There are 150,000 students in 136 elementary and 46 secondary schools. The city can consist of a single school district or a number of school districts which cooperate to gain efficiency and economy through the use of a common media system. The city is not the largest nor most densely populated in the United States. By way of comparison, New York City has approximately nine times the population, four times the area, and more than twice the population density of the city used in this study.

Metropolitan Area Model: The population of the metropolitan area is approximately two million. Its perimeter has an irregular shape and surrounds an area of approximately 1500 square miles. Because of its irregular shape, a circle with a 30 miles radius (2800 sq. mi.) is necessary to completely cover this area.

The metropolitan area, which contains a number of school districts, has 546 elementary and 183 secondary schools with a total of 600,000 students (K-12). It is assumed that these districts would cooperate with one another for some large media projects to achieve economy of operation.

State Model: The state has a population of about 4.5 million people. It does not contain a metropolitan area as large nor as populous as described above, though about 60 percent of the population is urban. It has an area of about 40,000 square miles and a population density of about 110 per square mile. Approximately one million students (K-12) are distributed among 920 elementary and 310 secondary schools.

Regional Model: The region is approximately a 10 to 1 extrapolation of the state, but a smaller population density is used to bring this figure closer to the national average. The region has an area of 550,000 square miles and a population of about 42 million. There are 10 million students in 9200 elementary and 3100 secondary schools. The region contains a few widely distributed metropolitan areas but no continuous corridor such as is found between Boston and Washington. (The corridor is considered separately in the full original report).

Educational Task Defined

The task assumed in this report is: To provide each student with material via some medium during a average of 10% of his actual instructional time. In reality, no subject is taught entirely by the use of a media system. Some subjects may not use the media system at all. More than 10% of some subject may be presented by a media system. This task is general in nature so that it may be applied to any system. Wher. a single system is considered for solving an actual problem, the task can be specified in terms of particular subject material and relative effectiveness of the media for the material.

A difficulty with respect to this study is not that the task is general in nature, but that it is not defined in units that have a relationship to system design. To bridge this gap, the following exercise is offered to illustrate the method used for this study to convert the general 10% of the defined environments. In a real situation, this exercise is unnecessary. The programs, lesson units, and other related factors would be determined from the educational objectives of the real situation.

Program Requirements for a Local Environment

What follows is a description of the method used in this study to estimate the approximate number of unique programs which would have to be produced or acquired to perform a generalized educational assignment over a period of one year. The method is applied to grades 1 through 12 in two separate groups: grades 1-8 and grades 9-12. Only the calculation for grades 1-8 is shown in this abridgment.

For this illustration, it is assumed that general program material (enrichment, background material, general science, etc.) is acceptable for use over a four-grade span (average), e.g., 1-4, 3-6, 9-12. It is also assumed that specific subject-oriented material is acceptable for use in a single grade and only by a portion of the students within that grade; for example, Algebra I may only be applicable to algebra students in grade 8.

It is assumed that the students in grades 1-8 are engaged in a single course of study, though this is not without exception. In some cases, course specialization may occur in grades 7 and 8; occasionally, elementary schools, especially private schools, may offer different courses. It is assumed that there are 900 hours in a school year.

180 days/year x 5 hours/day = 900 hours/year

It is assumed that 70% of the student's total time in school is available to receive media presentations. (This excludes lunch, study periods, etc.)

900 hours x 0.7 = 630 hours available for media presentation.

It is assumed that media will be used an average of 10% of this time.

630 hours x 0.1 = 63 hours average media usage/student/year

It is assumed that 50% of the material presented applies to only a single grade.

63 hours/grade x 8 grades x 0.5 = 252 hours of material for single grade use

It is assumed that 50% of the material is applied to an average of four grades (some material may apply to eight grades).

63 hours/grade x $\frac{8}{4}$ x 0.5 = 63 hours of material for multigrade use

252 hours single grade materials

63 hours multigrade materials

315 hours of unique material for grades 1-8

Total unique programming

grades 1-8 = 315 hours

9-12 = 655 hours (Calculation of this is shown in the full report.)

= 970 hours of 1,000 hours

It is assumed that each program is 20 minutes long.

1,000 hours x 3 program/hour = 3,000 unique programs to study

10% average media coverage in a local district

Program Requirements for City Environment and Above

If 1,000 unique program hours are sufficient to accomplish the task assigned to a single school district, will the same number of hours be sufficient for all the school districts in a state?

The concept of unique programming hours used in this study does not directly take into account the actual subject material involved. The method may be adequate to determine the average number of unique programming hours needed in a school or school district. However, an increase in overall program hours may be necessary when the task is applied to a larger environment such as a state or region. The 1,000 hours may be adequate to supply each student (on an average) in a school or district with 10% media usage or availability. Due to overall curriculum differences, such as a larger number of subject offerings and differences in teaching methods, the 1,000 hours of unique programming may be insufficient to provide 10% media coverage when applied to a large number of schools or school districts.

Taking this factor into account, the following number of hours of unique programming will be assigned to each area.

Local	1,000 hours
City	1,200 hours
Metropolitan area	1,300 hours
State	1,500 hours
Region	1,600 hours

Cost Structure

The stated task, to provide each student with material via some medium during an average of 10% of his total instructional time, offers a common source of data for the design of each media system. The definition of environments provides a method of examining systems as they are affected ty an alteration in the size of the environment.

Classification by Function--Analysis for cost estimation can be further aided by classification of the elements of each media system as they relate to production, distribution, and reception.

Production: Production costs are those incurred in the inception, creation, development, and preparation of the instructional content. The acquisition of media programs and its related costs, such as selection and other handling, are also classified as production costs. For a media system, these costs must include the cost of curriculum design, the use and development of research and evaluation teams, media specialists, facilities, and all the myriad of inputs necessary to produce a successful learning experience for the student. Specific examples are script writing and recording of programs for radio and television.

Distribution: Distribution costs are those incurred in changing or copying the material from its original form, if necessary, and sending it to a point at which it will be reconverted to a usable form for the student. Usually, the transmitted material is not in a form which is immediately useful to the student. Examples are duplicating original

tape and broadcasting for television, duplicating and mailing film from a processing center to a school, or duplicating and playing tape and transmitting to headphones in language laboratories.

Reception: Reception costs are those incurred in changing the form and presenting the distributed material so that it is useful to the student. Examples are antennas, TV sets, film projectors, screens, headphones, and carrels.

Classification as Capital or Operating Costs--Production, distribution, and reception costs can be classified as either capital (initial) costs or operating (annual) costs. Costs classified as capital costs include all purchases of goods and services that have a useful value of longer than a year or that are not incurred every year.

Equivalent Annual Cost: To simplify cost comparisons, the capital costs can be amortized over the life of the investment and added with interest to the average annual operating cost to form an equivalent annual cost. The result is a uniform yearly figure which includes authorization and interest. These costs can be examined for each environment to determine cost trends as they relate to student population, area serviced, etc. To calculate the equivalent annual cost, first a capital recovery factor (c.r.f.) is obtained from standard financial tables for a particular interest rate and life of the purchase. For example, the c.r.f. for five years and 1% interest is a little over 20%. The capital cost is multiplied by the c.r.f. and the product is added to the annual operating cost to obtain the equivalent annual cost.

Cost Structure Model

A cost structure can be established which encompasses the capital and operating costs for production, distribution, and reception for each system in each environment. This cost structure is illustrated in Fig.3.

Cube "A" illustrates an area of costs which is associated with the operating expenses during the production (acquisition) of educational material to be used by a media system in a metropolitan school environment. Cube "B" is symbolic of operating costs for distributing instructional materials within a local school district.

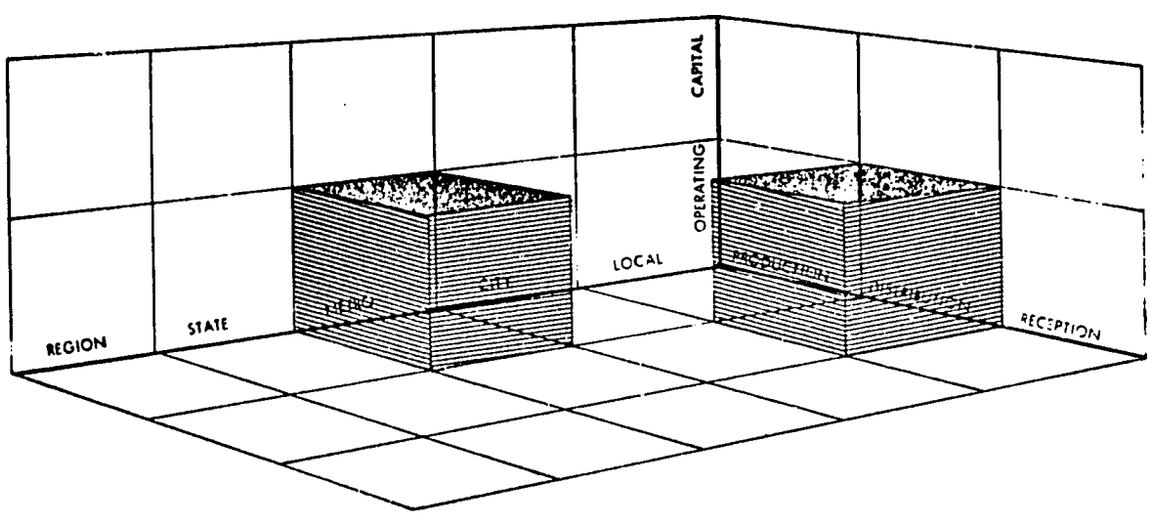

Figure 3. Cost Structure Model

Sources and Use of Cost Data

The collection of cost data pertaining to an element of a media system usually resulted in a range of costs, not a precise value. The costs were collected from the following sources: equipment catalogs, reports (both objective and subjective), private conversations, and personal experiences.

The sources of cost data are indicated in most cases in the full original report, but there are some instances where the source is not mentioned. These data costs are derived from the experience and personal investigation of the project participants. In those cases where the numbers presented need to be qualified, the type of interpretation which should be placed on their value is indicated.

To estimate total costs for the systems investigated, a single value for each item was selected from the range of costs collected. The choice was usually based on intuitive feeling of appropriateness for the environment. In most cases, the value selected might be the mode of the frequency distribution of selections by purchasing agents under the given conditions. The assumptions which were made to derive the estimated costs are included in the report as the need arises.

The actual dollar cost per system may not be directly applicable to a specific educator's unique problem, but it can indicate general cost trends. The value of this cost structure lies in the generality of its approach. The variables of a real situation can be applied to the structure to provide more realistic comparisons for an actual situation. The

cost structure might be looked upon as a tool which can be applied along with measures of "media effectiveness" to solve "real world" problems.

COST ESTIMATES

Costs were estimated for each of the media systems investigated using the basic model discussed in the previous section. (The detailed cost data are presented in the original study, available from the ERIC Document Reproduction Service.)

Graphical illustrations have been prepared from the cost data. There are two major sets of graphs presented and discussed in the full report. Each graph in the first set presents the production, distribution, and reception costs for one instructional media system. A second set presents graphical comparisons of the costs of media systems. Production, distribution, reception, and total costs are shown individually. (In this abridgment, detailed estimates are provided only for television, but comparisons between the different media systems are included.)

The following graph presents the production, distribution, and reception equivalent annual cost per student, i.e., annual operating cost plus amortization with interest. The cost per student is shown over the range of environments. The environments are listed across the bottom of the graph. Each of the five environments has a given number of students and the costs have been estimated only at these five points.

Television Production Cost

Fig. 4 presents the equivalent annual production costs, operating plus amortization, used for each television system. The production of instructional television materials can be treated independently of distribution and reception, and it is, therefore, presented and discussed before the individual television systems are presented. Three different costs for production of materials are shown.

Minimum Production Cost: This is the minimum estimated cost of producing usable instructional television material. It is based on a $300 per hour basic production cost plus a fraction of a rental cost of $145 per hour plus associated costs of administration, related materials, and research and evaluation. (Complete figures and rationale are shown in the full original report.)

High Quality Production Cost: This is an estimate of the costs of advanced state-of-the-art production based on $5,000 per hour production cost and rental at $145 per hour plus associated costs of administration, related materials, and research and evaluation.

National Programming Source Costs: This cost assumes that a national center provided copies of materials at a figure approaching the duplication cost. No such source of instructional material now exists.

The number of hours of programming in the model increases from 1,000 at the local level to 1,600 at the regional level.

The costs shown in Fig. 4 indicate that the cost of high quality production is $91 per student, which is certainly beyond the funding ability

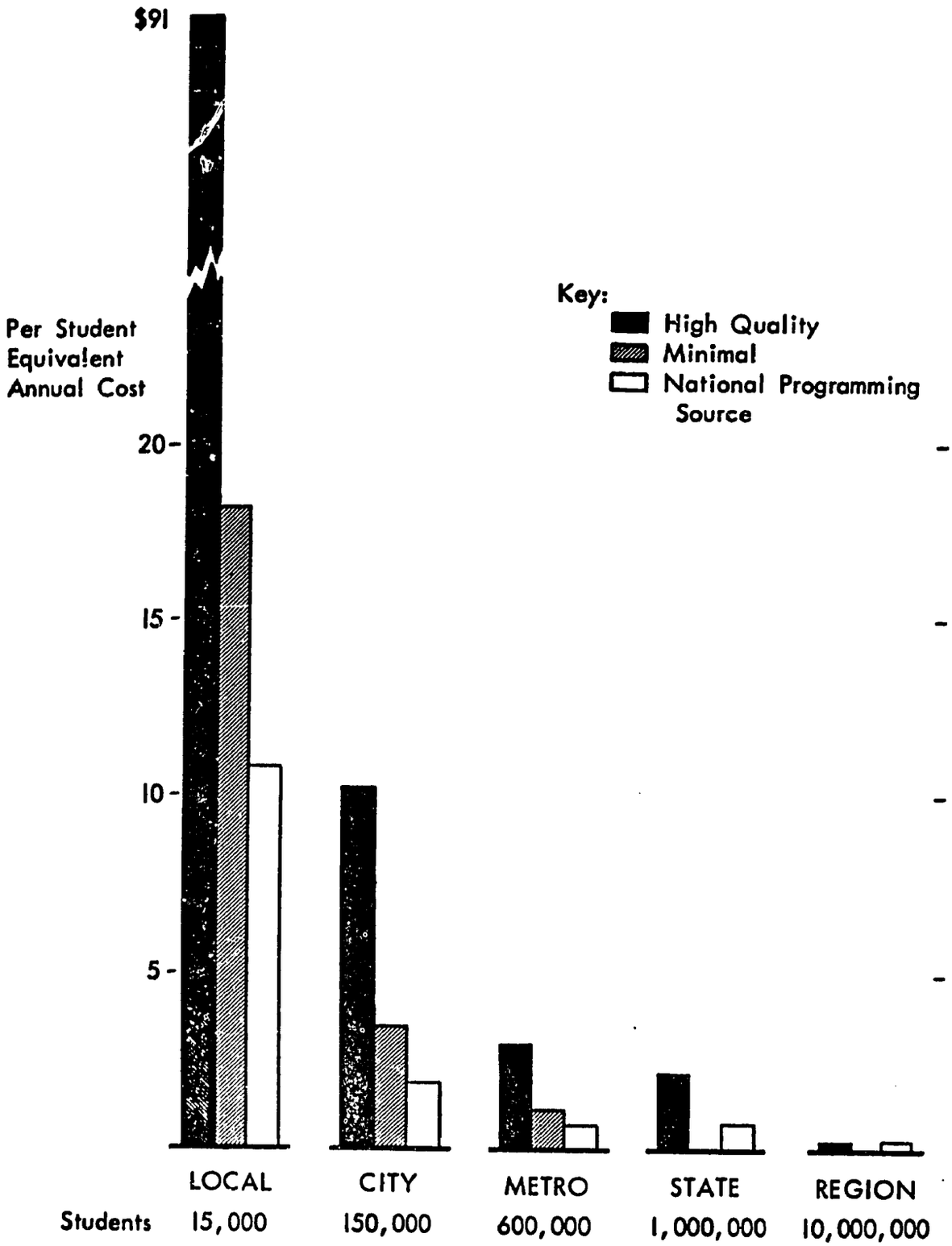

Figure 4. TV Production Costs

of a local school system of 15,000 students. The minimal programming cost for such a system is about $18 per student per year, which is still a large figure. Therefore, the minimum programming costs were used in the model for the local and city school systems. Although it would be desirable to offer the high quality materials in these schools, no school systems are presently able to do so. (If a different estimate of the cost is desired, the reader can substitute either the high quality or the national programming source costs shown in the tables in the full original report.)

The most important observation concerning production costs per student is that the cost decreases rapidly as the number of students increases. This behavior is typical of a fixed cost. The costs in the production category of the model are mostly those of producing the television programs. This programming cost has two variables, price and quantity. Quantity increases as larger areas are served. The increase in program hours is necessary because a wider range of student is encompassed by the larger system. An increase from 1,000 hours for the local environment to 1,600 hours for the regional environment was assumed in the model. Unfortunately, it is very difficult to estimate how large the increase should be. Even if it were 300%, the production cost for the largest system would be less than a dollar per student per year. The price of materials for the larger environments has not been increased directly, but the percentage of rented materials was decreased slightly. Fewer rentals means increased costs because rental is less expensive. In practice, the amount spent per program does seem to increase with the size of the area served, in contrast

to the constant cost per hour assumed here. This is mostly a budgetary effect. Larger schools have more money, but since their programming is almost always below the "high quality" level, they spend more per program whenever funds are available. Since high quality production is provided in the model, no such increase is needed here.

Looking at the annual production costs per student, it is encouraging to find that high quality materials can be produced for under $11 per student for all areas of city size or greater. If minimum programming is acceptable, even school systems of 15,000 can produce materials for under $20 per student per year. There is at least one system in the U.S.--the Washington County, Maryland, system--which is spending that much for programming. Finally, if a national center for copying a large supply of good materials were available, the programming cost would be about $10 per student for the local school and would decrease to only a few dollars for larger areas.

The production cost figure points to the need of school systems to cooperate in obtaining instructional television materials. It appears that any one school system will have great difficulty in financing its own production at any but a minimal level. Schools should join together in a cooperative production effort. It seems strange that no sizeable amount of cooperation in producing materials for physically separate distribution systems has taken place. The most obvious reason that cooperation has not been practiced is that each system has different problems and its materials reflect those problems. On the other hand, thousands of school systems use the same textbooks.

Equipment for Television Reception

The reception cost for each individual school must be computed before the actual reception equipment costs for a school district can be determined. The costs vary with the size of each school. An average cost per school could be obtained which would produce a fairly accurate cost extrapolation over areas larger than a single school district. This study will use two average costs, one for a small school (elementary) and one for a larger school (secondary). This method is used to illustrate that some costs vary with the number of television sets in use, and some costs are somewhat independent of this number.

The enrollment of the smaller school is 500 to 700 students. It contains 20 or more classrooms, and 20 rooms are wired for television reception. However, only 10 are supplied with television sets. This allows for future expansion or the use of portable sets which can be moved from room to room as needed. Ten television sets in this size school are adequate for the common task used throughout this study.

The larger school's enrollment is 1,000 to 1,500 students. It contains 40 or more classrooms. Thirty-five rooms are wired for television reception, and 20 rooms are supplied with television sets.

Television sets, stands, wiring of distribution coaxial cable, and a distribution amplifier are the basic reception equipment in all of the television systems. To the cost of the equipment is added the particular equipment costs which vary from system to system. Thus, the difference in reception equipment costs for each system consists mainly of the differences in antenna, preamplifier, tower, and converter costs for each system.

Standard 525 line 23-inch monochrome receivers are used throughout all of the systems. All of the system also use radio frequency distribution within the school building. No consideration is given in this study to special high resolution television systems using video monitors operating with rasters of more than 525 lines such as might be required in a medical school.

Included in the hardware costs are the costs of installation, sighting of antennas, and system checkout. Thus, some schools would actually have higher or lower reception costs. All reception costs are based on four-channel operation. Operation of fewer channels would not significantly reduce reception costs.

Brief Descriptions of T.V. Media Distribution Systems

Airborne T.V.- C-130 aircraft equipped with video tape recorders and transmitters would provide four channels of UHF television coverage over about a 200 mile radius for the state. Eight such systems would be required for the region.

ITFS - Four channels of standard Instructional Television Fixed Service equipment would provide service for the local and city environments. Five such stations would be connected by off-the-air pickup for the metropolitan system. The state and regional systems assume the use of a proposed higher-powered ITFS system with microwave relay between six stations for the state and 73 stations for the region.

UHF Broadcast Stations - Four channels of standard UHF broadcasting equipment would provide service for the local, city, and metropolitan environments. For the state and regional environments, microwave relay of the signal from a central point to each of 20 stations for the state and 154 stations for the region is assumed.

Closed Circuit T.V. - Coaxial cable and microwave facilities would be used to connect each school with a central distribution center.

Satellite T.V. - A synchronous satellite equipped for four channel broadcast was derived from the computer model of G.E.'s Missile and Space Division. This model was based on 1973 projected technology.

VTR - This system assumes that each school is equipped with 4 helical-scan video tape recorders and a complete library of tapes.

Brief Description of Other Media Systems

Film or Audio-Visual Media System - Equipping of each school with 16mm. sound projectors and a minor amount of equipment for slides, filmstrips and transparencies is assumed. Film prints are purchased by a central facility and circulated to each school by truck.

Educational Radio - A four-channel FM multiplex system would broadcast from separate stations, each obtaining tapes from a national production facility. Each school room is equipped with a receiver.

Learning and Language Laboratories - For the local and city environments, a 30 station interactive audio facility for languages at each high school and a 30 station non-interactive audio facility at each elementary facility is assumed.

Dial Access - The dial access system would consist of a central bank of audio tapes prepared by the teacher which can be presented over a classroom speaker upon demand in any classroom.

Comparison of Costs

The following graphs illustrate the equivalent annual cost per student of the production, distribution, reception, and total cost categories for all media for each environment. These graphs are used in discussing the cost comparisons of the media systems.

Production Costs

Fig 5. shows annual equivalent production cost for each media. The cost for production of television and film per student per year is quite high, but the production cost for television decreases rapidly from $18 to 25¢ as the number of students is increased. Recall that programming is the major portion of production cost. At the local and city levels, low-cost programming for television was chosen for the model while high quality programming was specified for the larger areas. In contrast, because of present film print pricing practices, the film cost for production does not decrease with higher numbers of students. It increases from $37 to $46 per student per year. The increase reflects the increase in the number of programming hours from 1,000 at the local level to 1,600 at the regional. The present pricing practices do not reflect the large increase in volume which is incorporated in the model, and might well change if an increased volume of prints were assured. Nor do the present pricing policies take

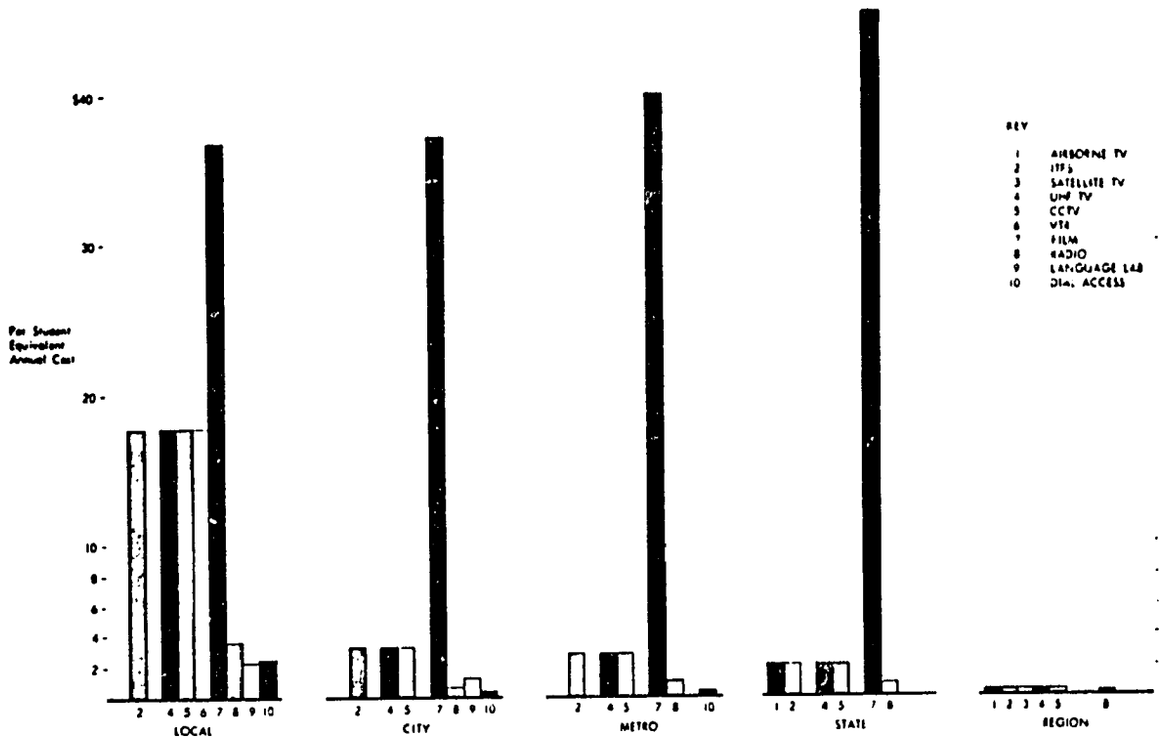

Figure 5. Production Cost Comparison

into account the possibility of producing coordinated series of lessons with a simpler instructional television format. These would probably cost considerably less per lesson. On the other hand, to change these practices would lead to abandoning of one of the peculiar advantages of film, i.e., the ready availability of a wide range of materials of high technical quality.

The costs for radio production are somewhat high, about $4, at the local level, but decrease rapidly with larger numbers of students. The cost for the metropolitan and other areas is approximately $1 and less. The costs are based on rates higher than the present cost of obtaining duplicates for the Educational Audio Network. The increased rate provides funds for producing new series of instructional materials. The radio production costs also include costs for noninstructional broadcasting of about $1 per 100 persons in the broadcasting area. The radio production costs are much lower than the television production costs.

The production costs for language learning laboratories, around $2 per student per year, is not strictly comparable to the production cost for the other systems. The language laboratories can occupy 10% of the student's time without 1,000 hours of unique programming, which is the amount of programming assumed for other media at the local level. Nor is it at all obvious that the student should spend 10% of his time using a language laboratory. Therefore, a figure of 225 hours of unique programming has been used in the model. The elementary schools are assumed to use a passive or listening-only system. Only a small amount of money has been made available for programming for the elementary schools.

The production cost for the classroom dial access system is quite low, i.e., $2 at the local level and considerably less than 50¢ at the city and metropolitan levels. The production cost includes 1,000 hours of tapes of various readings, events, music, etc., which are presently available at a low cost of about $10 per hour. Because the system has 67 channels, and because of the general nature of the material, the instructional technique

would largely consist of selecting short segments of the materials by the teacher. The teacher would assemble an instructional sequence for a particular class. This is quite different from the production of radio or television materials where the more limited number of channels assumed in the model means that most of the materials would be organized into complete instruction sequences by a central facility.

In summary, it can be said that production for visual materials can be accomplished at the reasonable cost of several dollars per student if the number of students in the system is in the hundreds of thousands. Moreover, the price structure for the materials must reflect the large volume. At present, television production cost is considerably less than the cost of producing films.

The production cost of aduio materials for the 10% task is less than $1 per student when the number of students reaches the level of 100,000. If teachers produce their own tapes or if the somewhat limited number of tapes now available is used, the cost is only a few dollars per student even at the local level. Each of the aduio methods is inexpensive to program at the city level.

Distribution Costs

Fig. 6 presents the equivalent annual cost of distribution for each instructional media system. The costs of many of the systems which were examined across the entire range of environments show the same type of behavior, i.e., decreasing cost per student in the range from local to city and metropolitan area and then an increase from the metropolitan to

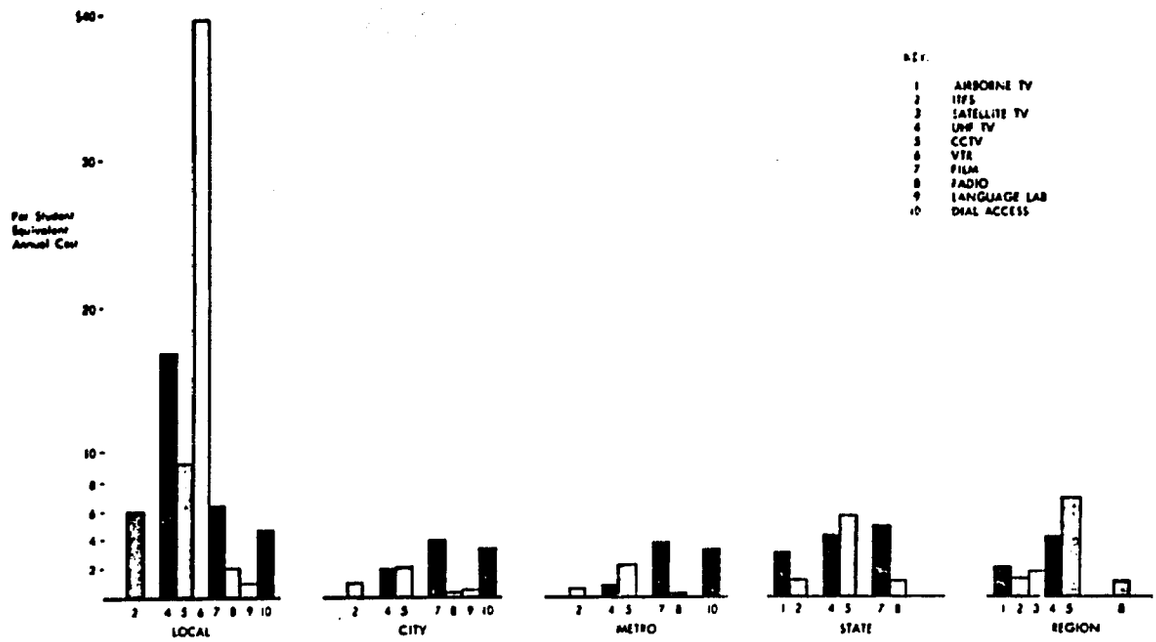

Figure 6. Distribution Cost Comparison

the state and regional levels. The change in the number of students per basic transmitting unit of the distribution system causes this behavior. The city and metropolitan areas have densities on the order of 1,000 students per square mile, which the state and regional densities have less than 50. In general, the higher the cost of the basic unit, for example a radio transmitter, the higher the cost per student for the local area but the lower the cost for the larger areas. The local area does not utilize all of the larger systems' potential.

The television distribution systems are relatively expensive to use for the local school system, but become quite reasonable for the city and larger areas at about $2 or less per student per year.

The lowest-cost television distribution systems are the present ITFS for local, city, and metropolitan area coverage and the new proposed higher-powered ITFS system for the state or regional areas. The UHF and closed-circuit systems are only $1 per student per year more than ITFS at the city level. It should be noted, however, that the costs for this new type of ITFS equipment are conjectural, since none has been produced or operated. Also, almost all of the cost difference between UHF and the proposed higher-powered ITFS is due to higher power, more attention to providing a readily available signal, better control and monitoring, and higher operational reliability of the UHF system. The two systems are almost the same from a technical standpoint. It would be feasible to change either service to more closely resemble the other, although the FCC would have to approve such changes.

The projected 1973 satellite costs of a little under $2 per student per year and the airborne cost, which is slightly more, are roughly competitive with the higher-powered ITFS system for larger areas. The cost of the airborne system declines from state to region because the coverage patterns fit together better in a larger area.

The VTR system which places a video tape recorder and tape library in every school is quite expensive, about $36 per student per year. The cost would not decrease for larger areas since the basic cost is multiplied for each school.

The radio distribution system is even cheaper than television, particularly at the local level where it is only $2 per student per year.

The language laboratory distribution system costs about $1.50 per student per year for all of the environments for which it was costed.

The dial access distribution system is the most expensive audio system at $3 to $5 per student per year, ranging from the local to the metropolitan areas. The dial access system was not investigated for state or regional areas, but the costs would probably increase substantially because of increased transmission line charges.

The film distribution system costs about the same as dial access or closed-circuit television. The costs are in the $3 to $6 per student per year range.

In summary, television and radio are both available for the city and/or metropolitan areas at less than $1 per student for distribution. In the local school district, the distribution cost of the language laboratory and radio system is considerably less than any other system, about $2 per student per year. The radio system is a high-powered service which can serve homes as well as schools 18 hours per day. Film or classroom dial access distribution can be accomplished for $3 to $6 per student per year depending upon the size of the area. The VTR in the school is not an efficient method under the assumptions presented in the model. Among the television systems, for distribution cost alone, the ITFS system is cheaper for the local and city areas. For the larger areas, only a change in FCC rules to permit higher power will allow ITFS to be competitive with UHF or airborne for the state and region.

It should be noted that effectiveness has not been studied, and that some of the fairly small differences in distribution costs may be offset by educational advantages or disadvantages.

Reception Costs

The equivalent annual costs per student for reception are presented in Fig. 7. The reception costs show a more constant behavior pattern as a function of area size than do the other costs.

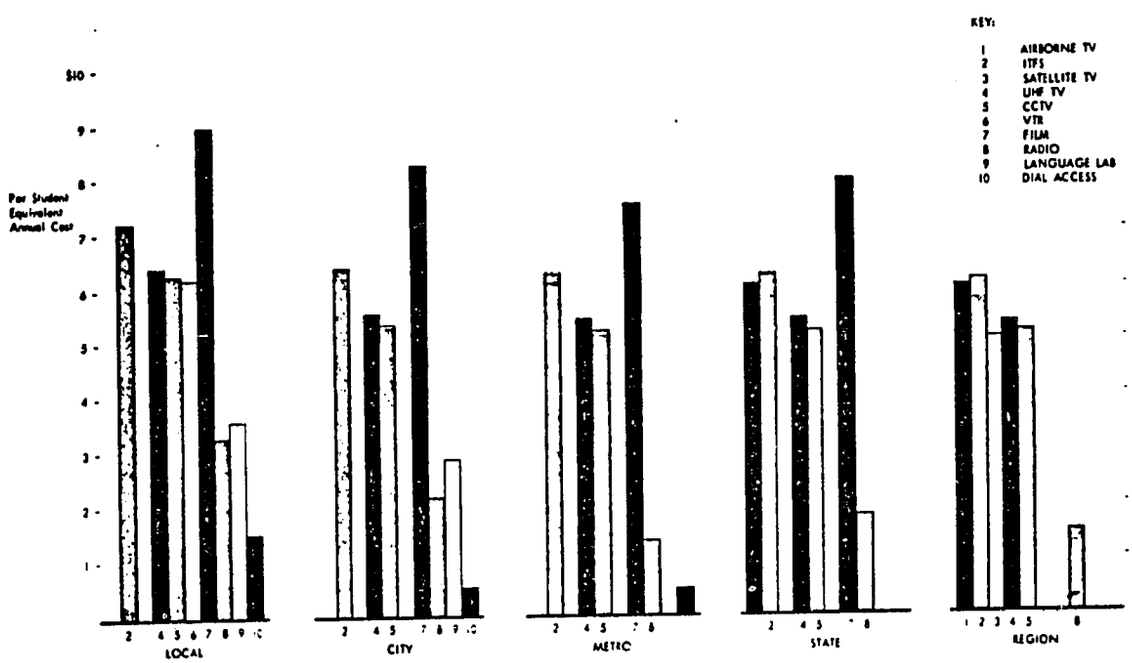

Figure 7. Reception Cost Comparison

The television costs fall in a band about $1 wide centering on $6.50 for the local system and decreasing to $5 per student per year for the regional system. Closed-circuit, VTR, and UHF broadcasts have the lowest costs. Airborne and ITFS have the highest costs because better antennas and towers are needed. The reception costs for the satellite system are projected at slightly less than the others because 1973 technology is assumed for this system. The present cost for this equipment would be considerably more. Approximately $2.50 of television reception cost per student is for teacher training and another $2 is for the television set.

The radio reception cost decreases from about $3 per student at the local level to about $1.50 per student per year at the regional level.

The film reception cost is about $9 for the local system but decreases to $8 per student per year for the metropolitan area. Film reception costs is the highest of all the media, but is only insignificantly higher than the television reception cost for the metropolitan area.

The language learning laboratories reception costs are slightly higher than radio reception costs because they include the carrel.

The reception cost for classroom dial access is the cheapest of the media--less than $1 per student per year at the city and metropolitan level. The dial access reception equipment consists of one loudspeaker per room.

In summary, television reception cost--including $2.50 for teacher training--is about $6 per student per year. The reception cost for closed-circuit or VTR network is slightly more than for the other television systems. Film reception cost is somewhat more. The reception cost for radio is about

$2 except for the local area where it is about $3 per student per year. The reception cost for the language laboratory is slightly more than for radio. The classroom dial access cost for reception is very low, about 50¢ for the city or the metropolitan area.

Total Cost

The total equivalent annual cost per student is shown in Fig. 8, and is perhaps the most important costs of all.

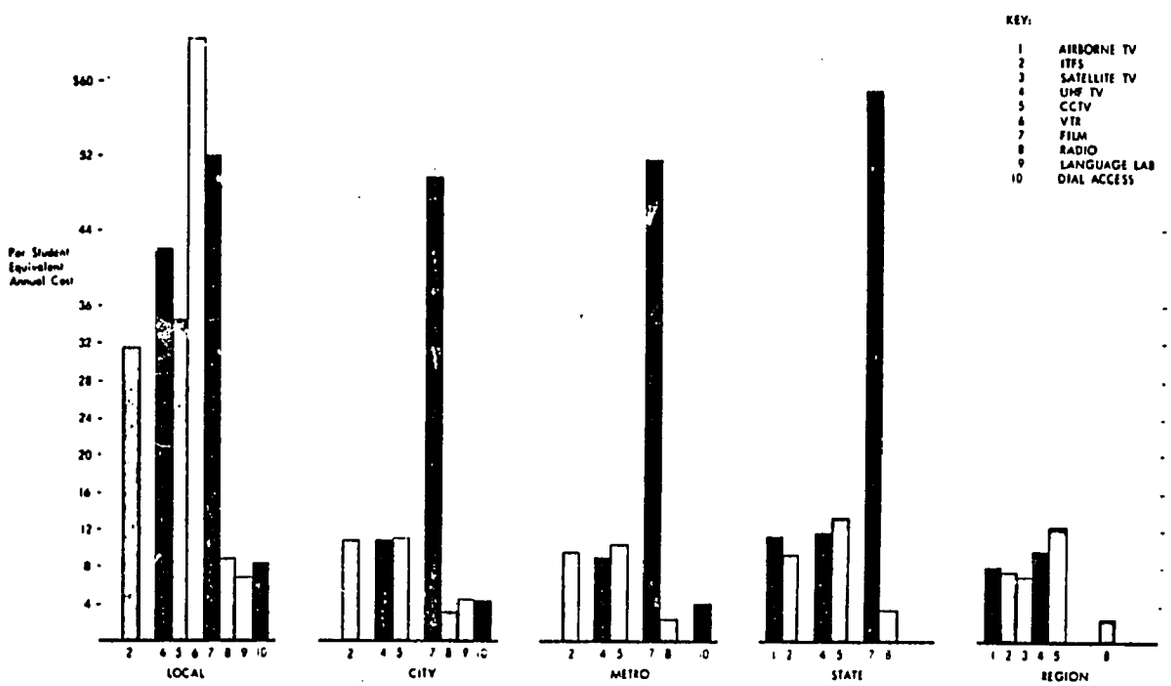

Figure 8. Total Cost Comparison

The total costs fall into two broad bands with only a few exceptions. The television total costs (except for the VTR system) fall between $30 and $40 per student per year for the local area (5% to 10% of yearly expenditures). They converge on $10 for the city and roughly the same for the metropolitan area. They then spread to a range of $6 to $14 for the state and regional areas. The 1973 satellite has the lowest total cost but only by an insignificant margin. The ITFS system is less in the local areas. For the city and metropolitan areas, costs are so close that technical questions of channel space would probably be more important and would no doubt favor the closed-circuit system. Much the same can be said for statewide multichannel systems unless FCC rules are changed.

The results for the audio systems, language learning laboratories, classroom dial access, and radio systems form the second band and all fall in the $8 to $10 range for the local area and in the $3 to $6 per student per year range for the city. The radio system is about $2.50 per student per year for the metropolitan area and $3.50 and $2.50 for the state and region, the lowest cost of any system.

The VTR system with video tape recorders in each school costs about $65 at the local level, considerably more than any of the other systems. As cheaper and more reliable machines, high speed duplication, or the CBS Laboratories' EVR system become available, VTR should be given additional attention.

The total costs for film are about $50 per student for the local, city, and metropolitan areas, but rise to about $59 per student per year at the state and regional level.

In summary, audio instructional materials can be supplied by radio for as low as $2 to $3 per student per year. Visual material costs are about $10 per student per year when they are delivered by television in the city or metropolitan areas. Several new methods are available for coverage of wider areas at about the same or slightly lower cost. Smaller school districts must cooperate with one another or pay considerably more.

Effect of Number of Channels and Task Size on Cost Per Student

The cost figures presented in the discussion of television and radio have been costs for a four-channel service. The four channels accommodate the defined task of 10% of student time with a considerable margin for repeated broadcasts and expansion. There is, of course, the possibility of changing the task and/or changing the number of channels. An estimate of the cost of doing this is shown in Fig. 9 and Fig. 10.

Fig. 9 presents the change in cost with a switch in the number of channels from four to two and one for selected television systems. The figures are obtained from those in the descriptions using the same production and reception costs per student and the distribution costs for one and two channels. It is assumed that a single six or eight-channel converter to UHF can be designed. The additional cost is quite small, little more than $1 for six or eight channels. Regulatory limits on the number of channels might preclude such additions, however.

Fig. 10 considers the effect of a change in the level of the task accomplished by the instructional media system. The basic level of the model is 10% of student time. For a 20% task, the programming portion of production

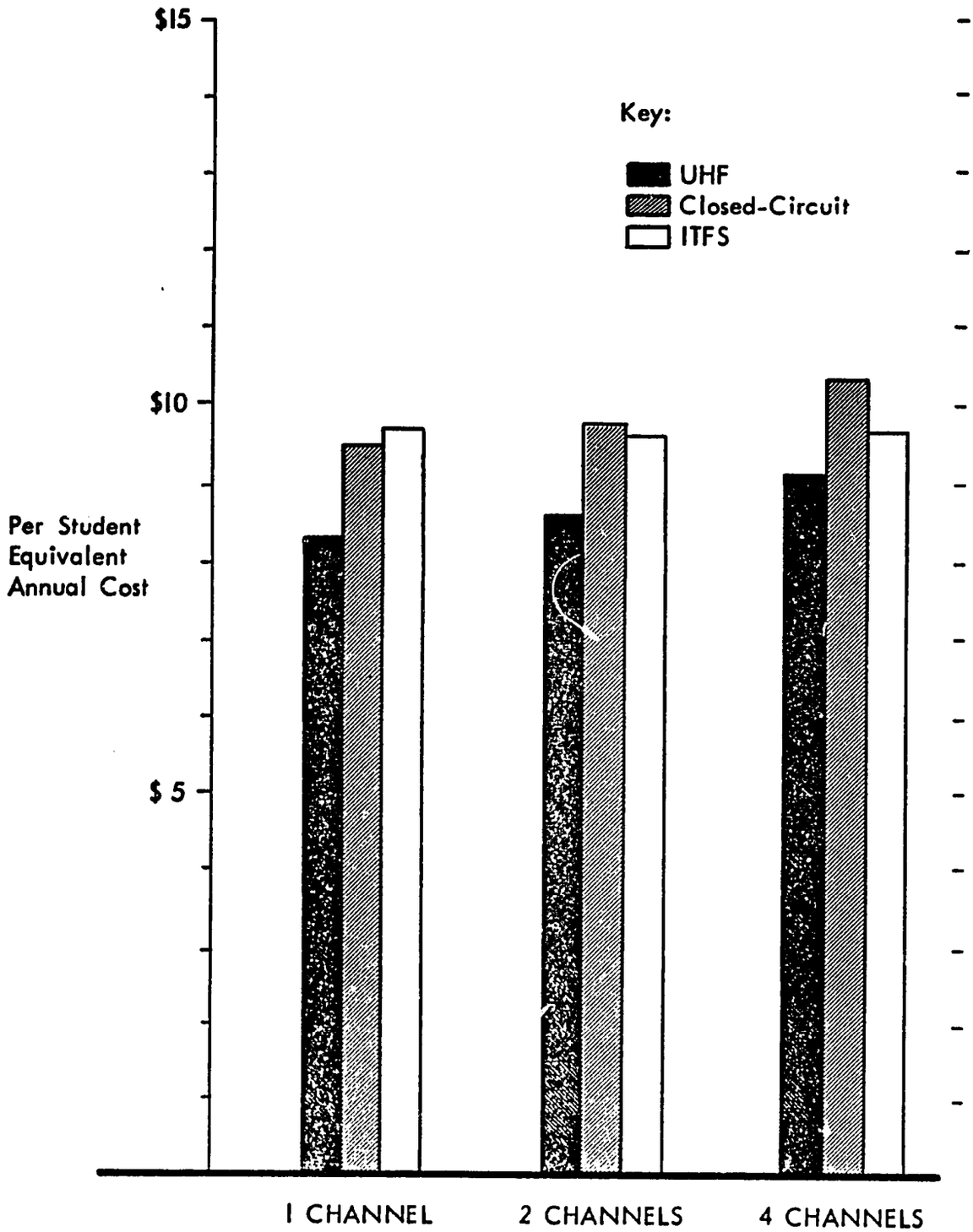

Figure 9. Estimated Effect of Number of Channels on Cost–Metropolitan Area

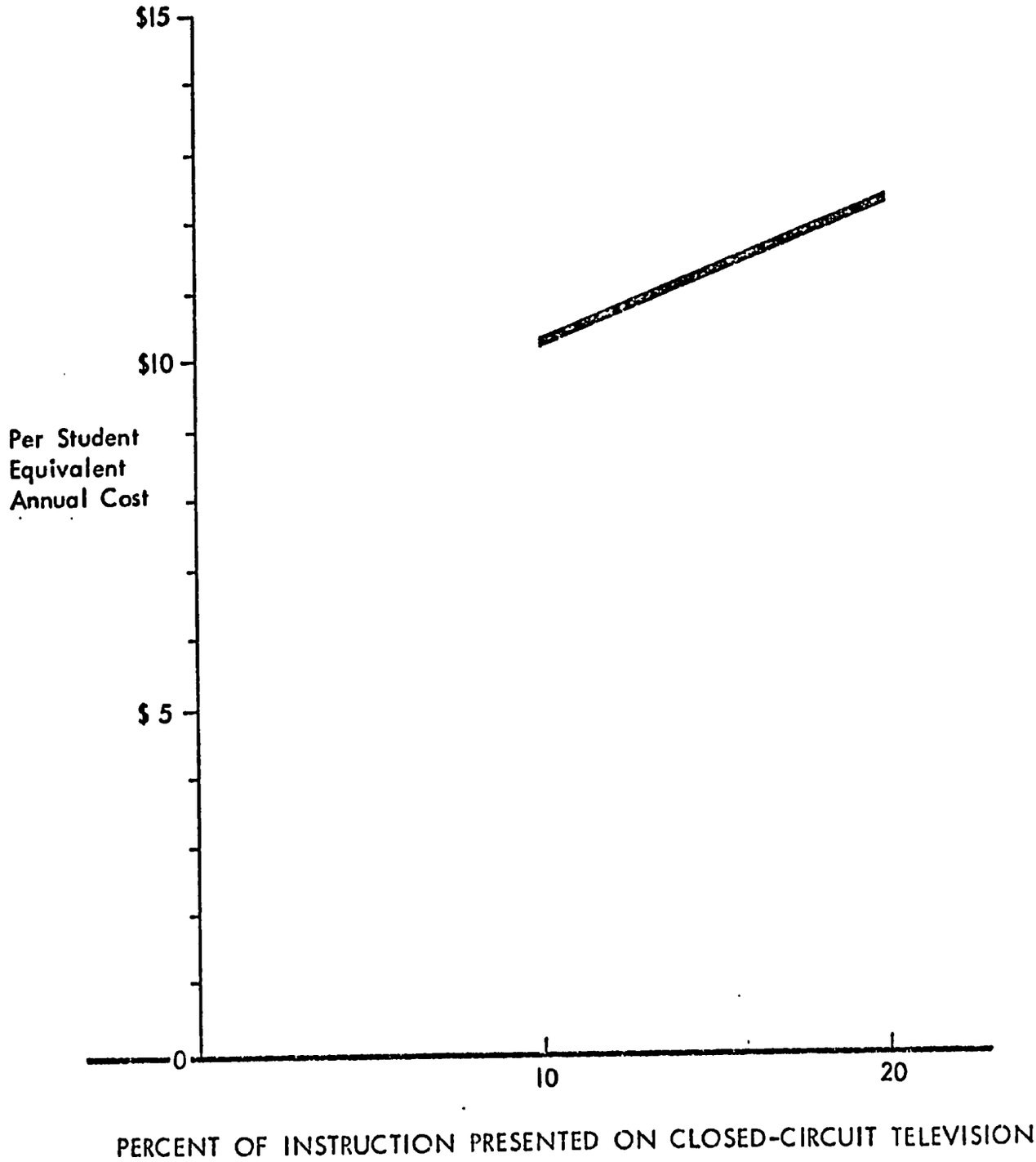

Figure 10. Estimated Effect of Task Size on Cost--Metropolitan Area

cost would almost double. Other costs would remain about the same. The result, roughly a 20% increase in total cost, is shown in Figure 18 for the closed-circuit metropolitan system. Other television systems at the metropolitan level would change the same amount, given the above assumptions.

A combination of the two changes--a 20% task and an eight channel system--would result in an increased cost of only about 30%, but this is only a very crude estimate.

COST-SAVINGS CONSIDERATIONS

One objective of this study was to investigate ways in which costs in instructional media systems could be reduced. This section serves two purposes. The first is to present an overview of how cost savings may be achieved, the second to present suggestions which may lead to possible cost savings through organizational changes in the educational systems.

Three areas can be identified where changes are necessary if cost savings are to be achieved:

1. The utilization of media systems,
2. The technology of media systems, and
3. The organization of educational systems.

A discussion of each of these three areas is presented in this section.

Utilization of Media Systems

Wide-scale adoption and more intensive use of the media will result in cost reductions on a per student basis in the areas of production, distribution, and reception, as discussed below.

Production Cost Savings from Increased Utilization

Significant savings will result if a production effort can serve a larger number of students. However, if materials are to be accepted for widespread use, the quality of content and presentation must be improved by making more effective use of learning theory, techniques to motivate students, and studies of the curriculum needs of the schools. Presentation of materials

in this manner would result in an increase in overall production cost but, through wider utilization, would also result in a decrease in production cost per student.

Savings in quality production are predicated on the assumption that the need for materials is relatively uniform in widely scattered school districts and that reliable, convenient distribution and reception systems would be available to transmit these materials. The existing widespread adoption of the same textbook would seem to indicate that these assumptions are reasonable. However, some coordinating mechanism is needed to guide the production and distribution of materials for the newer media. The cooperation of school districts is an essential ingredient in the development of such a mechanism.

Fig. 4, earlier in this abridgment, illustrated the cost savings possible through wider utilization of the materials produced for television. The cost per student drops rapidly with the increase in the number of students served. This cost decrease occurs although there are two assumptions in the model which would tend to have the opposite effect: (1) the number of hours of material required increases 60% from the local to the regional environment, and (2) the quality of material changes from "minimum" at the city level to "high" at the metropolitan level.

Distribution Cost Savings from Increased Utilization

The distribution cost per student can be reduced if

1. More students can be served from a central facility, or
2. Mass reproduction methods can be found for making inexpensive copies of original materials.

The service of a media system can be increased through the use of network television techniques--higher transmission antennae, increased transmission power, and the electronic relay of materials between school districts. Satellite and airborne television systems are also well suited to covering vast areas containing large numbers of students. More intensive use of such methods can reduce per student cost considerably, but only if materials and schedules are appropriately tailored to the educational needs of participating schools. To accomplish this, transmission centers must have multiple channels available, and schedules and materials must be coordinated with the schools.

Fig. 11 shows the behavior of distribution cost for broadcast television systems as a function of the number of students served. The cost per student decreases sharply over the range from the local to the metropolitan level. On the other hand, no decrease occurs from the state to the regional level because the population density does not increase; in other words, the utilization of any one station does not increase from the state to the regional level.

The critical factor in lowering the cost of reproducing original materials is the anticipated volume of distribution. Unless the volume is large enough, the development effort required to find inexpensive methods of duplicating films and video tapes would not be worthwhile. Present copying techniques are based on high quality broadcast standards and low volume. Although high speed reproduction of video tapes is potentially possible, the necessary techniques have not been developed. The price of a film print is many times the cost of making the print because of the low recovery rate of production

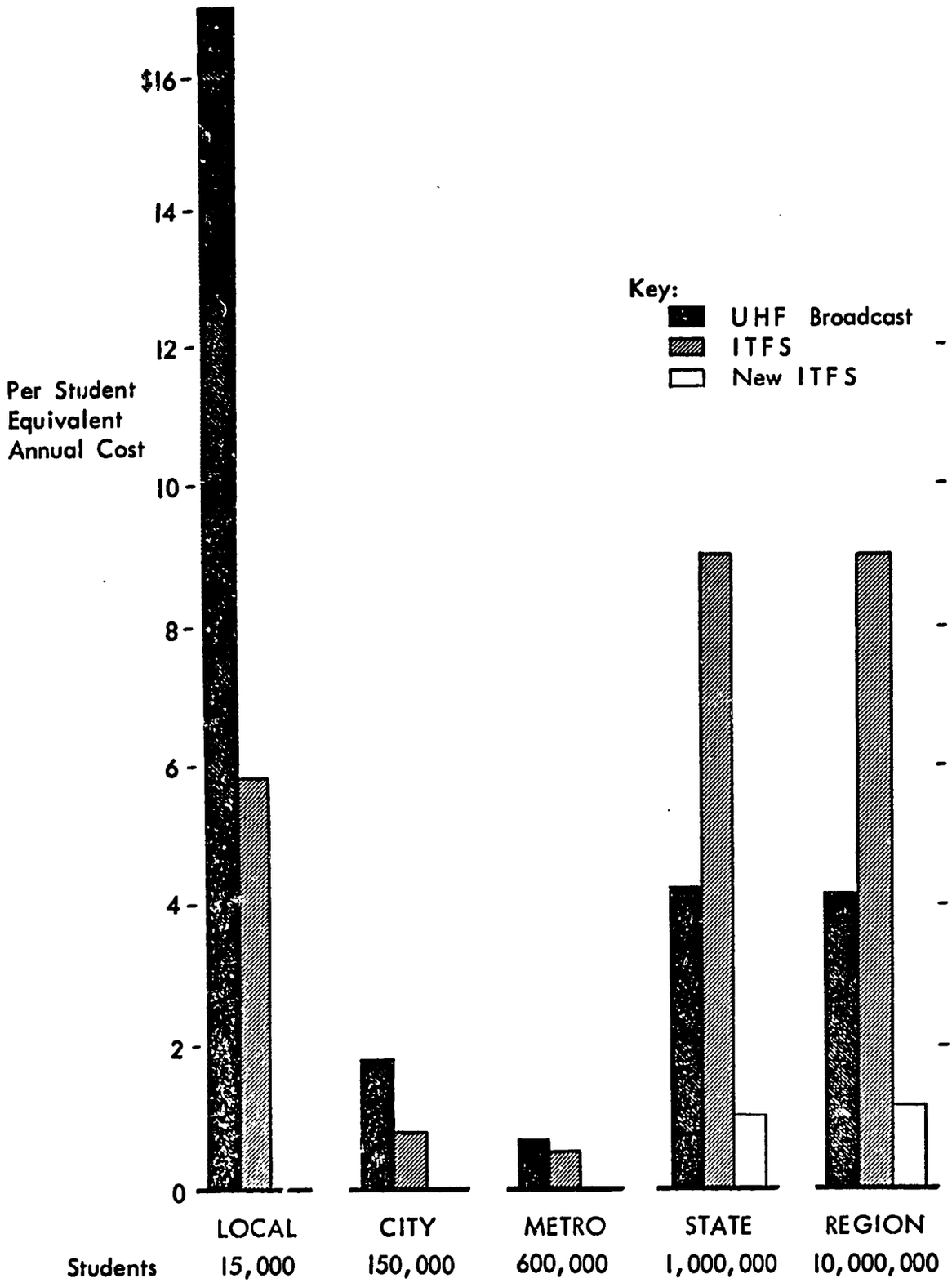

Figure 11. TV Distribution Costs

and marketing costs. Assurance of a high-volume market for copies of video materials or federal financing of the needed research would encourage low cost reproduction methods to copying video educational materials.

Reception Cost Savings from Increased Utilization

Savings in reception costs can be effected through

1. Increased student utilization of some portions of the reception system, and

2. Lower costs of components through the adoption of mass production methods.

Portions of the reception system would cost less per student if more student hours were devoted to the media. The central reception and distribution segments in the television reception systems are examples of areas where greater utilization would lower per student cost. However, since most of the reception cost is for the television set and teacher training, more students in the schools would not necessarily lower costs per student. The students would still need a television set and a trained teacher.

The discussion above shows that an increased number of students using a media system tends to lower per student costs. Also, there is another increase in the utilization of the media which would tend to affect cost favorably, i.e., the increased use of the system by the same students. Although the actual cost per student would rise as the system is expanded, the cost does not increase as rapidly as service is increased. Therefore, if total educational costs are considered, more intensive use of media systems may be desirable since the change in the cost of providing additional units of instruction is quite small.

Improved Technology for Instructional Media

Improvements in the instructional media technology should lower the cost of the media. Several technological advances are suggested in this volume. For example, the satellite system is not now in existence; the higher-powered ITFS system is a new proposal. The suggested use of a four-channel television system would also be an innovation. Some aspects of the classroom dial access and language laboratories are new, and the multiplex radio system is not now in educational use.

Organization of Educational Systems

The behavioral objectives and the types of learning associated with those objectives are key elements in the media selection process. The mode of presentation whether group or individual, is also an important consideration in the selection procedure. If these elements play a part in the selection of a media system, it may be assumed that the need for both group and individually-oriented systems will be recognized. Would this change the traditional school organization? Yes, because there are few provisions for individualized instruction at the present time. Could these changes result in "cost saving" situations? Again the answer is "yes."

The cost savings which could result from changes in the organization of educational systems should probably be referred to as increases in "cost effectiveness." Most of the previous discussion has tended to equate cost savings with reduced costs. In this discussion cost savings will be equated with cost effectiveness.

The largest item in a school's operating budget is teachers' salaries. The implementation of media systems would not necessarily reduce the number of teachers. It would alter their role, however, so that they could devote a larger portion of their time to individual instruction and the guidance of learning experiences. This would be one step toward the achievement of optimum "cost effectiveness." The operation of media, the monitoring of learning experiences, and other similar responsibilities could be assigned to paraprofessionals. This work, currently performed by the teacher, could be effectively accomplished by persons without the professional qualifications required of members of the teaching staff. Hence, a "cost saving" may result when a school system is organized along these lines.

The discussion of wider utilization of media systems indicated the cost savings are possible when the system is used by larger numbers of students. For example, a dramatic decrease in annual cost per student for the production of television material occurs as the number of students increases from 15 thousand to 10 million. The per pupil cost of the distribution portion of the media system is also favorably affected as the number of students increases in the area served by the system.

Wider utilization may reduce cost, but it may also present organizational problems. For example, if 11 states were to be served by the same instructional satellite system, the educational programs of those states would have to be coordinated.

If production costs are to be shared, the material must be acceptable to all of the participants. Therefore, the user schools must be involved in the design, development, testing and evaluation, and revision of materials.

The financial arrangements to support the production of materials must be agreed upon. All of the above considerations would affect the present organization of the user schools.

A distribution system which serves more than one school or district also presents problems. The scheduling of "what and when" can be a horrendous task. Again, the organization of the schools using the system is affected by the scheduling, so these schools must cooperate to determine the policies of a central distribution facility.

The media cannot be effective unless the teacher is trained to make use of the capabilities which the media system provides. Therefore, teacher training is of prime importance, and the educational system must provide adequate training. Teacher training may tend to increase per student cost, but lack of training in the use of the tools provided by media can affect cost effectiveness immeasurably.

The scope of this report does not include the investigation of designs for the effective organization of educational systems, but this discussion has been included to point to some of the ways in which media system cost reductions and cost effectiveness are related to the organization of the educational system.

REGULATORY IMPLICATIONS

Electronic Systems

Some of the multichannel instructional television systems proposed in this study are not explicitly covered by the present regulations to policies of the FCC. Specifically, the higher-powered ITFS specified for the state and region, the four-channel UHF system, the UHF airborne system, and the use of satellites for direct transmission on the 2500 MHz frequencies are all somewhat outside established practice. These departures were made for two reasons, cost and regulatory tardiness.

The production costs for instructional media for the local school system of 15,000 students were found to be $60 per student per year for high quality programming, $15 per student for minimal quality programming, and $6.67 for copies of materials produced by national sources. The distribution cost was almost $6 per student, even for ITFS, which has the lowest cost. These high costs decrease as more students are served and should encourage schools to share production and/or distribution efforts by joining an area-wide system such as a metropolitan, state, or regional system.

The possibility of a wide area multichannel instructional television system is limited under present FCC regulations and policies. An examination of the policies regarding multichannel wide area systems shows that these limitations make it impractical to implement a large scale instructional television system outside of a metropolitan area. Existing regulations are examined below.

The UHF frequencies are designated as broadcast frequencies. The Communications Act of 1934 defines broadcasting as "the dissemination of radio communication intended to be received by the public." The FCC regards this definition as separating instructional television from broadcasting since ITV is not intended for the entire "public." FCC policy is that instructional service, if designed for instruction alone, should not be placed in the UHF band. Multiple channels would be particularly hard to obtain for educational purposes. Recent FCC actions which give evidence of this viewpoint are the denial of the NAEB request for multiple-channel educational reservations in the latest UHF allocation table, the denial of the Georgia State Board of Education petition for a block of 30 UHF channels, and the refusal by the FCC to allow the airborne television project to continue using the UHF channels assigned to it.

The FCC has specifically allowed educators to use the 2500 MHz band on a shared basis with other users for a three year period ending in 1966. As of 1968, no final action has been taken. This service, the Instructional Television Fixed Service or ITFS, was set up at the urging of an electronics firm which desired an additional marker for its low power microwave relay transmitters. The service is low power, localized for individual school systems. Use of low transmitting heights and directional transmitting antennas is recommended. Paragraph 26 of the Report and Order on Docket No. 14744 of the FCC specifically bans use of ITFS "to distribute material over an entire state or a large portion thereof." Even when used within a metropolitan area, the FCC concept of shared use

of ITFS channels has required the concurrence of all school districts in the area before service can be instituted. Such service is not economical for wide area coverage, as is shown in the standard ITFS cost figure for state coverage in the full original report.

The airborne system was given until 1969 to relinguish its UHF channels and went off the air in June 1968. Meanwhile the FCC designated six ITFS channels in the midwest for its use. Airborne broadcast on even four ITFS channels in any area except that covered by the midwest airborne project would have to obtain the explicit permission of all school districts within its area, according to the present FCC policy. This would be difficult.

The use of a satellite for direct telecasting is not covered by FCC regulations. There are strong political and economic forces that must be overcome before such an operation would be approved.

The only alternatives to the telecasting methods discussed above are closed-circuit systems and the portable video tape recorder, neither of which uses the airways. These are by far the most costly systems, as was shown either in Fig. 8. Neither of these systems is within the province of the FCC unless microwave is used or state lines are crossed.

In summary, the use of the airwaves for multichannel instructional television for a wide area has been almost precluded by present FCC regulation and policy. Since such a system has considerable cost advantages, several instructional media systems which would be difficult to establish under present FCC policies and regulations were included in this report. The systems which are specified can be justified in terms of channel

allocation and the economics of providing the service if a priority were assigned for instructional service. A brief justification for each of the systems follows.

The four-channel UHF instructional system could be accommodated if the FCC would recognize the difference between instructional service and other broadcasting. The taboos--limitations on close spacing of channels--could be changed. The taboos were eliminated for ITFS in recognition of this fact. Reservation of a block of channels for instructional systems was thoroughly studied for the Georgia State Board of Education proposed and found to be practical. A block of 20 channels would be sufficient for a four-channel state or regional service. In the UHF channels 52-72 or 63-83, there are only the merest handful of broadcast stations operating. They could be moved down into the region below 52 or 63 if some of the allocations to mail communities were deleted from the allocation table or if a more "saturated" allocation table were prepared. It has been shown that the great majority of the UHF station allocations will not be used in the foreseeable future because they are not economically feasible. It has been said that the FCC is thinking of transferring a portion of the UHF broadcast channels to the land mobile service for this very reason.

The four-channel airborne system was generally assumed to be opearting in the UHF in this study. However, it was noted that the transmitting equipment could be produced for about the same price at the ITFS frequency. Thus, the airborne system could operate at either frequency except for regulatory considerations. Extensive analysis of the allocations in the midwest in 1964 showed that there were adequate channels available for both a six-channel

airborne instructional system and all the commercial stations which would be economically feasible in the foreseeable future. The same is probably true for all regions except the eastern megalopolis, which has been treated in a separate statement in the full original report.

The low power of the present ITFS system does not make it economically feasible for use in a large area. For this reason, a higher-powered, wide-area ITFS service is proposed in this study. The reason for examining the state and regional areas is because the local school system cannot afford programming for the multichannel systems. A state or region system is the only way to serve the small school districts if they are outside of a metropolitan area. While the local school system may find scheduling advantages in the use of ITFS, there are serious problems of financing the production of materials for telecasting. The FCC's recent pamphlets on ITFS points to the desirability of renting materials rather than producing them in each school system. Unfortunately, there are not adequate rentals available and even rental is expensive for the small school system. Many schools are proceeding with live production without adequate resources, personnel, planning or experience. Many thousands of schools will soon undergo the frustrating programming experience which ETV stations have experienced during the last 15 years.

The proposed higher-powered ITFS system would include a 20 channel block for the state or regional system, leaving four to six blocks of two or three channels per block within the present ITFS allocation for purely local use or for local retransmission to avoid scheduling problems.

The satellite system in this study is on the same frequency as ITFS. It is assumed that provision could also be made for a few channels of local ITFS service, as would be done with the higher-powered ITFS.

The problem of frequency allocation is currently under inspection by several groups on a national and international level. This is a particularly opportune time to make adequate provision for instructional television.

In summary, without a national program source, only a state or regional system can economically provide multichannel instructional television for the local school. The FCC does not provide for such a system. Therefore the assumption has been made that the regulations can be changed. It is suggested that economical and efficient four-channel systems can be instituted at either UHF or ITFS, leaving sufficient channels still available for local commercial and educational interests.

Film System*

Some cost efficiencies in a 16mm media system could be realized with a favorable outcome of the current copyright legislation. Unfortunately, Congress is trying to develop a piece of universal legislation that will satisfy both the author and the publisher of all art forms for all communication media, both commercial and educational. A proposed draft of suggested copyright changes was authored by members of National Association of Educational Broadcasters for the Department of Audiovisual Instruction of the National Education Association. The bulk of this draft was adopted as the official position of the NEA, which then recommended the changes to Congress. These recommendations have provoked considerable discussion during the past two years.

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* This section is by Joseph E. Lynch

The fair use doctrine was expanded to permit a school to make one copy of a film without obtaining permission from the copyright holder, use it once, and then destroy the copy. Certainly this clause can only tempt honest individuals to break the law. On the other hand, modern photocopying equipment allows individuals to infringe upon the existing law every day. The textbook publishing industry has helped to create this problem by refusing to allow teachers to duplicate passages from books for testing purposes. Schools are permitted to make a duplicate video tape copy of an existing film program, but it is doubtful that they will destroy the copy once made. Accordingly, most producers and distributors charge exorbitant prices for schools for the right to copy. They feel that permitting video tape copies of films will decrease their sales to a school system because the schools will use the multiple transmission capabilities of television rather than buy enough films for the classrooms. No research has been done to prove or disprove this argument.

Another area of infringement, according to legislation now in effect, is excerpting short segments of footage from longer films. This can be resolved easily by establishing a national facility which would catalog existing film footage, source, and price. Footage cataloging is virtually nonexistent today and would require computer cataloging procedures to describe sequences.

A difficult area, avoided by the proposed copyright bill, concerns films that were produced by federal government grants. A few years ago marketing or distribution right for films, texts, and other materials were

given to corporations which then priced these items at commercial rates. Competitive companies complained about the exclusive distribution rights, educators complained about the commercial prices, and the federal government was in the middle. No group of commercial companies would cooperate and market the programs on a nonexclusive basis. Also, they would not allow the program development agency to market their programs because they feared government competition.

As curriculum development programs continue to be funded by various agencies of the federal government, some nonexclusive distribution contracts have been negotiated. However, a new problem has developed. Publishers, distributors, etc. refuse to accept a program the way it is designed, but rather wish to change content and/or form to be consistent with their own programs or manufacturing capabilities. For example, if a program consists of 10 odd sized booklets each having 10 pages, a publisher would package it in one volume of 100 standard textbook size pages. One solution to this problem is to fund the curriculum groups and allow them to develop their own distribution capability. Another alternative is to help individuals from the educational and commercial communities to establish new companies for this purpose by funding the initial capital requirements of these groups. Currently the Small Business Administration is slow to loan money for the formulation of this new type of company.

In summary, if a national program source is not available, 16mm film programs could still become less expensive if the following steps were taken:

1. Redraft the current copyright bill to better serve the needs of educators and commercial producers.

2. Create a national cataloging service so that schools can locate short film segments that best fit their needs.

3. Permit films that were produced with federal funds to be sold at less than commercial prices.

4. Permit curriculum groups to market or distribute newly developed materials.

APPENDIX IV

Excerpts from

Notes on Cost-Effectiveness Evaluation of Schooling in Developing Countries

By: Dean Jamison
Stanford University

June, 1972

*The work on this paper was supported by AID Contract csd3284 to the Institute for Communication Research, Stanford University.

*I am indebted to M. Jamison, S. Klees, J. Leslie, and W. Schramm for helpful conversations concerning aspects of this paper. Parts of the paper draw on my recent collaboration with Patrick Suppes, and his inputs have been of considerable value in my thinking about these matters.

....II. ALTERNATIVES FOR SCHOOLS

In this section I describe in broad terms the [instructional] alternatives for schools. I first categorize these alternatives along a number of dimensions and then more specifically discuss the alternatives on the dimension most critical for cost-effectiveness analysis. That dimension concerns the mix of instructional technologies, which has the most direct impact on cost. The set of alternatives actually available to a decision-maker depends, of course, on his budget and Subsection III.C introduces that constraint explicitly.

A. Categorization of Alternatives*

The categories of alternatives that I will use are:

1. degree of physical centralization,
2. mix of instructional methods (including the conventional classroom),
3. amount of time the student spends in school,
4. curriculum mix, and
5. certification, promotion, and retention procedures.

I discuss each of these briefly below, then focus in more detail on those most critical for a cost-effectiveness analysis.

Advances in communication and information storage technology have made possible a considerable decentralization of schools. A first level of decentralization would be to perhaps very small-

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*A category that will not be discussed here is that of organizational alternatives. In the United States now there is discussion of a number of organizational structures differing from those now in common use; these include performance contracting, community control, and voucher finance.

neighborhood schools. The next level of decentralization would be to the correspondence-school concept where the students receive their lessons at home by audio or video lessons (stored or off the air) and interact with the school system by mail or, for developed countries, through their own terminals. This latter alternative need not preclude gatherings of students for athletics, social occasions, or seminars and discussions. Going in the other direction, one can conceive of much larger school groupings than now exist; one argument in favor of these larger groupings would be to promote social and racial integration.

My own guess is that at the elementary level there are only very limited productivity implications for several fold increases or decreases in the present sizes of schools, though I feel this issue should be further examined. Further, in the rural areas that predominate in developing countries, there may be little choice about the size of schools unless one wishes to consider extensive student transportation and residential schools.

The second category of alternatives concerns the mix of instructional methods. I use the term mix to emphasize that in most departures from the present method of instruction the student will be learning from several instructional techniques during the day. In one mix there might, for example, be 2 hours of ETV in a class of size 60 with one paraprofessional and one older student monitoring, 2 hours of conventional class activity (size 27), 1/2 hour with a teacher in a discussion group with 5 or 6 other students, and 10 minutes at a CAI terminal. Clearly a great many mixes can be built from the basic array of technological and organizational alternatives now available, and we discuss these possibilities in more detail in the following section.

The third dimension of alternatives concerns the amount of time students spend in school--the number of hours per day and the number of days per year. In most countries elementary students spend 4 to 6 hours per day for about 180 days. Using present techniques of instruction, the length of the school year impacts very

strongly indeed on costs and it is probably of considerable importance in student learning. There is one further aspect of the "time" question that is much discussed by economists. For students in the higher grade levels, it is argued, there is an opportunity cost to the economy of having the student in school. In estimating the true cost of education one should, then, add in the earnings foregone by students due to their being in school. Schultz [1971] estimates that in the U.S. today the value of earnings foregone by high school students averages somewhat more than $500 per year and for college students somewhat more than $1,200, though much ambiguity surrounds these figures. Schultze further estimates that by about the year 1900 the earnings foregone by primary students had dropped to zero in the U.S.; at present an important use for schools, at this level at any rate, is to provide day-care or "babysitting" facilities. He estimates that approximately half the cost of schooling at the upper levels in developing countries may be in earnings foregone. In the discussion of costs in this paper I will simply note the amount of school time required of students without attempting to assign a value (positive or negative) to it.

The fourth category of alternatives concerns curriculum mix. This has a relatively limited impact on cost so we will not deal with this issue at any length here. It is perhaps worth noting, however, that in one of the very few instances in the United States where performance contracting in schools seems to have improved student performance (over controls) in reading and arithmetic there was a heavy relative emphasis on these subjects in the curriculum -- see Hall and Rapp [1971]. Whatever the appropriateness of this sort of curricular emphasis, its results lend support to the hypothesis that time of exposure to a subject is quite important among the things that schools can influence.

The final category of alternatives concerns promotion, retention, and certification procedures. The range of options here depends to some extent on the state of testing technology. Though testing and certification procedures have only a small direct

impact on cost, they have an important indirect impact through their influence on the number of students in the system. We return to this point in Section V where drop-out and promotion rates play a central role in evaluation of the alternatives.

B. Mixes of Instructional Methods

The second dimension of alternatives we discussed in Section II.A concerned the mix of instructional methods, construed to include the present method of instruction that involves a teacher in front of a classroom of students as well as various technologies. I first sketch the conventional alternatives then the technological ones. Section IV then briefly reviews what is known about the performance of the various alternatives in terms of their impact on student achievement.

Conventional Alternatives. The conventional alternatives to the present system fall into several relatively simple categories. These are:

1. Changes in teacher quality (i.e., level of intelligence, education, or experience).
2. Changes in the average number of students per class.
3. Changes in the average number of hours per week and weeks per year the studentspends in school.
4. Changes in the utilization rate of classrooms.

The feasible conventional alternatives can be characterized for any given annual budget for primary education, B, and number of students to be enrolled, N .* Let q be a measure of teacher

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*A more general characterization is given in II.C; as the formulation outlined here provides more detail on the conventional alternatives, I include it nonetheless.

quality (for operational simplicity, q may have to be a simple measure such as percent of teachers fully qualified or average educational attainment of teachers) and let $W(q)$ be the average annual wage (for full time work) of teachers when their quality average is q. Let C be the average class size, i.e., the average number of students in a classroom with a teacher and let h be the average number of hours per week a student is in class. Assuming, and this assumption can easily be relaxed, that a full tim teacher is in class 36 hours per week, the student to teacher ratio, S, is given by:

$$S = 36C/h \ . \qquad \text{(II.1)}$$

Increasing class size thus increases S, as does decreasing h.

To continue, let U be the average usage rate of classrooms, i.e., the average number of times they are used per day and let P be an imputed annual price for a classroom. Since the available budget was B and the number of students was N, an average of B/N per student per year is the basic cost constraint. Each student consumes $1/S$ or $h/36C$ teachers and $1/UC$ classrooms during the year. Thus the following equation holds as an approximation that includes only the major costs:

$$N[(h/36C)W(q) + P/UC] = B \ . \qquad \text{(II.2)}$$

Equation II.2 summarizes all "conventional" alternatives for the primary system in broadbrush terms. It fails to capture nuances but it specifies, nonetheless, all combinations of teacher quality, class size, hours of class per week, classroom usage rate, and students enrolled that are possible at the prevailing budget, prices, and wages.

If educational research were to the point where planners had functions relating school performance measures to C, q, h, and U, it would become a (relatively) simple mathematical problem to maximize number of graduates per year, say, subject to a budget constraint of

B per year; however, educational research is nowhere near this point. Thus, the approach that will be suggested later is to choose several values of the control variables that differ in different directions from the present values then to estimate the consequences for enrollments and graduates. This gives an idea of the direction in which planners should be moving, even if it fails to say how far they should go. It then allows for comparison with the technological alternatives.

Technological Alternatives. It is somewhat more difficult to categorize the technological alternatives than to categorize the conventional ones. There seem to be two broad dimensions along which the alternatives can be arrayed. The first is alternative technologies and the second is alternative uses for technology. Alternative technologies include:

1. Television.
2. Blackboard or still frame television, i.e., television that presents only alphanumeric characters or line drawings on the one hand or still pictures on the other.
3. Classroom controlled audio-visual media, including tape cassette players.
4. Radio.
5. Computer-assisted and computer-managed instruction (CAI and CMI; with CAI the student is on-line to the computer, with CMI he is off-line).
6. Programmed self-instruction.

Alternative uses for technology include at least the following five possibilities:

1. Enrichment of learning, i.e., provision of occasional lessons or experiences that the classroom teacher cannot easily provide.
2. Total replacement of the teacher in one or more subject areas.

3. Substantial supplementation of the teacher in one or more subject areas.

4. Teacher training.

5. A simultaneous mix of 3 and 4.

Shramm, Coombs, Kahnert, and Lyle [1967] review instances where new media have been used for many of these tasks, as well as for out of school education.

Since six technologies were listed, and five alternative ways of using technology, there are a total of 30 broad "technological alternatives". The next subsection indicates an approach for determining which combinations of these are feasible within a given budget constraint.

C. Alternatives and the Budget

Suppose we are allowed a certain budget, B, per student per year. Any realistic budget completely rules out some alternatives (e.g., 4 hours of CAI per day with 2 hours of private tutoring) while allowing others. The set of alternatives that is actually available is constrained by B and other restrictions.* Here we focus on the budget constraint and assume that B can be divided into five separate components:

$$B = I + S + F + A + T + P , \qquad \text{(III.1)}$$

where I = instructional costs,

S = space (or building) costs,

---

*There are, of course, a great many legal restrictions that vary from country to country but that often put bounds on class size, length of school day, teacher qualifications, etc. In any particular analysis, one must decide on the extent to which these constraints are to be considered immutable.

F = food costs (if applicable)

A = administrative costs, including testing and certification,

T = transportation costs for students, and

P = cost of physical education and recess.

The above symbols refer to costs per student per year. Each of the five categories of alternatives listed in II.A impacts on these costs in different ways. The degree of centralization impacts on S, T, and perhaps A and F . The mix of instructional technologies and the amount of time students are in school determine I . Time in school also affects F, T, and P but probably not A or S since the administrators and schools are there anyway. As mentioned previously, the curriculum mix and certification procedures do not impact too strongly on per-student costs (though they may well affect the number of students at the secondary level).

For the remainder of this discussion I consider alternatives available for primary and secondary schools assuming approximately the present degree of centralization of the system. That simplifies the analysis by enabling us to just examine how time and the mix of instructional technologies affect I , assuming other costs constant. As I accounts for 50% to 80% of school costs in developing countries, this is of central importance. I do feel, however, that examination of the cost impact of a highly decentralized system, i.e., out of school education, should be undertaken.

I turn now to presentation of a framework for arraying the instructional alternatives given any budget level and the assumption that there will be no major change in the degree of centralization of the primary or secondary schools. I ignore as second order the effects of the length of the school year on F, T, and P ; thus the analysis centers on how the mix of instructional technologies and the amount of time the student spends in school are constrained by the instructional budget I .

Assume that we consider n separate "technologies" of instruction.* A teacher with a class of 30 would be one technology, the same teacher with a class of 35 still another, etc. Let f_i be the average fraction of time per day that technology i is used, let h be the average number of hours per day of instruction, let d be the number of days per school year, and let c_i be the cost per student of using technology i for one hour per day. Then

$$I = \sum_{i=1}^{n} dhf_i c_i \ . \qquad \text{(II.3)}$$

The set of points $a = (f_1 \ldots\ldots f_i \ldots\ldots f_n;\ h;\ d)$ satisfying equation II.3 such that $f_i \geq 0$ for $i = 1,\ldots,n$; $\sum_{i=1}^{n} f_i = 1$, $0 < h < 24$, and $0 < d < 365$ then consists of the set of instructional and temporal alternatives for any one student. If c_i were known for all i one could assign a cost to each alternative and then group the alternatives into equal cost sets for comparison with one another. However, c_i is not only somewhat poorly known but also depends on a variety of factors, including the number of students using the system when fixed costs are important. As an approximation to c_i we assume the following functional form:

$$c_i = \frac{r_i + s_i}{N_{i1}} + \frac{t_i}{N_{i2}} + \frac{p_i}{N_{i3}} \ , \qquad \text{(II.4)}$$

---

*The term "technology" is used here in the economist's sense to denote any method of instruction. The alternatives here include, then, the conventional alternatives discussed in the preceding subsection.

where N_{i1} = number of students in the classroom using technology i,

N_{i2} = number of students using the delivery system (hardware) of technology i,

N_{i3} = total number of students who use technology i during all its years of use,

r_i = reception cost per class per hour (e.g., an imputed hourly rental of a TV set) of technology i,

t_i = delivery cost per hour of technology i,

p_i = total cost of program preparation, evaluation, and revision, per hour of technology i, and

s_i = cost per hour of teacher or classroom supervisor of technology i.

This formula is only an approximation for a number of reasons including the possibility that r_i and t_i depend on the number of hours of use the classroom hardware and the centralized hardware get, the possibility that annual cost is not strictly proportional to d, and the possibility that one should discount the value of students who use the program later in time. Nonetheless I feel that obtaining reasonable cost estimates within this framework is a useful step and facilitates the structuring of equal cost alternatives for evaluation. Section III deals with costs in more detail.

The central point of this section has been that the appropriate way to formulate the instructional alternatives is through a budget constraint equation. To do this one needs to know (at least approximately) the costs of the alternatives, and equation II.4 represents one mechanism for breaking down the costs. Given costs, equation II.3 then implicitly delineates the mixes of instructional methods feasible given any per student annual instructional budget I. (For a fixed overall school budget the available set clearly expands as one decreases the number of students in school.) The next section discusses cost estimation in more detail then Sections IV and V addresses the effectiveness side of the analysis by suggesting methods for choosing among the obviously vast number of alternatives available within the budget constraint....

III. COST OF ALTERNATIVES....

B. Unit Costs of Educational Technology Projects

Consider an educational technology* project that costs C_t in year t where C_t includes all expenditures on the project that year whether capital or recurrent. Let N_t be the number of students using the technology in year t and let the social rate of discount be r. The concept I wish to introduce is that of the unit cost from time i to time j of the project, which I will denote U_{ij}. Equation III.2 defines this concept formally and following that I illustrate its use with an example.

The following formula gives U_{ij}:

$$U_{ij} = \frac{\sum_{t=i}^{j} C_t / (1+r)^{t-i}}{\sum_{t=i}^{j} N_t / (1+r)^{t-i}} \qquad \text{(III.2)}$$

---

*The concepts developed here are as applicable to non-technology projects.

The basic idea behind this formula is that it sums the total expenditures on the project between years i and j and divides that total by the total number of students benefiting from it in those years. Both the costs and the number of students are discounted back to time i by the social rate of discount r. A decision-maker at time i can in no way influence expenditures or student usage before time i so that costs and benefits incurred up to that time are for his decision irrelevant and are not incorporated into U_{ij}. What U_{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 U_{ij} behaves as j varies, the decision-maker can obtain a feel for how long it will take for unit costs to fall to the point of making continuation of the investment worthwhile. When the decision-maker is considering whether the project should be undertaken at all, he should let $i=0$; i.e., he should compute U_{0j} for various values of j.

In order to illustrate the concept of unit cost from i to j I feel a textual example to be appropriate. To simplify matters, I will assume $r=0$; that is, there is no discounting of the future.

With this assumption equation III.2 simplifies to: $U_{ij} = \sum_{t=i}^{j} C_t / \sum_{t=i}^{j} N_t$.

For the example consider a province that wishes to provide one hour per day of ETV to each of the six elementary grades at the schools in the province. Assume that program preparation costs $2,000 for each of the 6 times 150 hours required and that, once taped, the

programs last indefinitely. One-third of the programming is prepared each year for the first three years, and one year of programming is prepared before any students use the system. The TV transmitter costs $200,000 and its annual operating and maintenance costs are $20,000; it is installed at the beginning of the first year of broadcasts to students. The remaining cost component is TV receivers and those are assumed to cost $200 each. Approximately 10% of the receivers need replacement each year and power and maintenance for the receivers is assumed to come to 10% of their purchase price each year. By multiple use throughout the day, about 100 students are able to share the cost of a single receiver.

We assume that 50,000 students start viewing after the first year of programming is complete, another 50,000 after the second year, and still another 50,000 after the third year. Thereafter, there are no changes in the size of the audience of 150,000 students. The TV receivers are purchased in the year they are needed. Table III.1 shows the cost components as a function of time, as well as the number of students. From the final two columns of Table III.1 one can compute U_{ij} ; before the project begins it is appropriate to compute U_{0j} , and Table III.2 shows the result of that computation. Column b of Table III.2 shows the total amount (in thousands of dollars) projected to have been spent on the project up to year j ; column c shows the total number of thousands of students projected to have received one hour per day of bTV up to year j . Dividing b by c , then, gives the total cost per student if the project were to end in year j . After 5 years, the cost has dropped to $5 per student per year and after 7 years it has dropped to $3. U_{0j} thus shows to the decision-makers how unit costs decrease as j increases.

Similar computations could be made for U_{1j}, U_{2j}, etc. I do not include those computations here but simply note that for $i \geq 4$

TABLE III.1: Costs and Usage of Hypothetical ETV System

a	b	c	d	e	f	g	h	i
		transmitter cost		receiver costs				
t	programming cost	purchase	use	initial purchase	replacement	maintenance	C_t	N_t
0	600	0	0	0	0	0	600	
1	600	200	20	100	0	10	930	5
2	600	0	20	100	10	20	750	10
3	0	0	20	100	20	30	170	15
4	0	0	20	0	30	30	80	15
5	0	0	20	0	30	30	80	15
6	0	0	20	0	30	30	80	15
7	0	0	20	0	30	30	80	15
8	0	0	20	0	30	30	80	15

Notes: 1. All costs are expressed in thousands of dollars.

2. N_t is the number of thousands of students receiving one hour daily of instruction by ETV in year t.

3. Column h is the sum of columns b, c, d, e, f, and g.

4. The text describes how the figures in the table were arrived at.

TABLE III.2: Unit Costs Viewed From Year Zero

a	b	c	
j	$\sum_{t=0}^{j} C_t$	$\sum_{t=0}^{j} N_t$	U_{0j} (=b/c)
0	600	0	∞
1	1,530	50	30
2	2,280	150	15
3	2,450	300	8
4	2,530	450	5
5	2,610	600	4
6	2,690	750	4
7	2,770	900	3
8	2,850	1,050	3

Notes: 1. C_t and N_t are from Table III.1.

2. U_{0j} is expressed in dollars per student receiving one hour of ETV per day for a year.

and $j \geq i$, U_{ij} = \$80/150 = \$.52. That is, a decision-maker in year 5 who is deciding whether to continue the project should consider his unit costs to be \$.52 per student per year independently of his time horizon.

In concluding this subsection I should stress that what has been presented is only a way of looking at unit costs, not of ascertaining whether what was paid for would be worth the cost. Nevertheless, as these unit costs enter in a central way into the specification of alternatives given by equation II.3, it is of value to gain insight into how they vary with time and student usage. I will soon make available analyses from the present point of view of the unit costs of the television component of educational reforms in El Salvador and the Ivory Coast.

C. Opportunity Costs of Educational Technology....

If a school system's per student expenditure is constrained by equation II.3, then having more of any one thing implies there must be less of something else. For this reason, it may be useful to a decision-maker to see explicitly what these opportunity costs are for certain important categories of alternatives. Since the largest expenditure category for schools is presently teacher salaries, we will examine the opportunity cost of introducing something new (e.g., educational television or radio) under the assumption that it will be "paid" for with less teacher input. Let S be the student to teacher ratio (this is not necessarily the same as class size -- see II.A) before the technology is introduced, and let W be the teacher's annual wage. Let $A(N)$ equal the average annual cost of the technology if N students use it 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 . As the post-technology instructional cost equals [W+A(N)(S+I)]/ (S+I) the following must hold:

$$W/S = R[W + A(N)\ (S+I)]\ /\ (S+I)\ . \qquad \text{(III.3)}$$

To find the increase in student-to-teacher ratio required to pay for the introduction of the technology, equation III.3 is solved for I giving:

$$I = [SW(I-R) + A(N)S^2R]\ /\ [W-A(N)\ SR]\ . \qquad \text{(III.4)}$$

I represents, then, the opportunity cost of introducing a technology in terms of increased student to teacher ratio. Table B.8 in Appendix B shows values of (S+I)/S for several values of N and R and for a number of ways of introducing radio into the Indonesian elementary education system. While the formula of equation III.4 was developed for expressing the opportunity cost of introducing a technology in terms of student to teacher ratio, similar formulas could be developed between other pairs of inputs. All such formulas would essentially represent ways of analytically evaluating the tradeoffs within equation II.3.

This completes the discussion of basic cost concepts. We now turn to a very brief review of what is known about the effectiveness of alternative instructional techniques.

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*The term instructional cost here denotes the cost of the teacher plus the cost of the instructional technology.

IV. EFFECTIVENESS OF ALTERNATIVE INSTRUCTIONAL TECHNOLOGIES

My purpose in this Section is to give references to surveys that have examined the effectiveness of alternative instructional technologies, including the "technology" of traditional classroom instruction. Patrick Suppes and I are currently preparing a critical survey of the effectiveness of the following technologies: traditional classroom instruction, instructional radio, instructional television, programmed instruction, computer-managed instruction, and computer-assisted instruction. That survey will be made available as soon as it is complete.* Here I will simply mention some of the available evidence concerning traditional instruction, instructional radio, and instructional television.

Much of what we know about the effectiveness of traditional instruction has been obtained from survey data of which the most extensive example is reported in Coleman, et. al. [1966] in their study on Equality of Educational Opportunity. About 20 analyses of the Coleman and similar data are now available, including some studies involving longitudinal data. Several surveys of these studies now exist and the reader is referred to them as a good introduction to the original studies; these surveys are by Guthrie [1970], Katzman [1971, Chapter 2], Averch et. al. [1972], Anderson and Greenberg [1972], and Wells [1972]. A general conclusion that emerges is that school variables explain little of the variance in scholastic achievement, though there are a few such variables -- for example, the teacher's verbal ability -- that do seem consistently related to scholastic performance. Most important from the point of view of educational planning is the finding that class size seems to little affect student performance; since total cost is highly sensitive to class size (or student to teacher ratio), this finding is of considerable practical importance. These survey findings on class size are supported by experimental studies -- see Smith [1972] for a discussion of these issues.

* Jamison, D., Suppes, P., & Wells, S. The effectiveness of alternative instructional media: A survey. Technical Report 196. Stanford, Calif.: Institute for Mathematical Studies in the Social Sciences, Stanford University, approximately November, 1972.

There is by now considerable experience with use of instructional radio, though good evaluational information is difficult to find. A number of recent surveys describe some of the experiences with instructional radio and the reader is referred to those -- Chu and Schramm [1966, Chapter VI], Leslie [1971], Forsythe [1970], and Smith [1972]. If supplemented with appropriate printed material it appears that radio can teach about as well as television for most purposes. The October 1968 issue of the Educational Broadcasting Review contains a bibliography of articles in this area.

The most comprehensive review of studies of the effectiveness of instructional television is that of Chu and Schramm [1966]. Their findings are well known and I will not repeat them here. Generally, television teaches about as well as a well educated classroom teacher. It can teach most subjects and at most grade levels, though its relative performance does seem to vary with these factors.

My general conclusion is that the medium appears to make little difference. What does seem to count for a student with a given set of characteristics is time of exposure to the subject matter and the organization and clarity of presentation. The economic importance of this conclusion concerning effectiveness is obvious.

V. EVALUATION OF ALTERNATIVES....

The discussion in this Section concerns the elementary school level in order to be concrete. Similar models could be developed for the secondary level. I should also note that the model developed in this Section is incomplete, theoretically as well as empirically, and the present author and a graduate student are continuing its development.

A. Basic Model*

The basic model of the system uses three standard concepts of educational planning: drop-out rate, progression rate, and repetition rate. These terms are occasionally subject to alternative interpretations, so I will define my usage of them explicitly.

α = drop-out rate = fraction of students in given grade who sometime during, or at the end of a school year leave school for good.

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*The model developed in this subsection is a linear model of flows within a school system and thus has similarities to models developed by Armitage, Smith, and Alper [1969] and Davis [1966].

β = <u>repetition rate</u> = fraction of students in a given grade in a given year who repeat the grade, either the following year or later. (It will be assumed in the model that the number of students in a given year who will repeat any grade after a lag of one or more years equals the number who have left previously and are returning that year.)

γ = <u>progression rate</u> = fraction of students in a given grade who proceed to the next higher grade the following year.

The model makes two assumptions about flows within the system -- the first of which is very natural, the second only an approximation.

Assumption 1. $\alpha + \beta + \gamma = 1$.

Assumption 2. Each of the six elementary grades have the same values of α, β, and γ . This assumption is often a reasonable approximation given inadequacies of existing data; it can easily be relaxed if the data allow more refinement.

This model enables us to predict flows in the system over time. Let $S_t = [s_{1,t}, s_{2,t}, s_{3,t}, s_{4,t}, s_{5,t}, s_{6,t}]$ be the vector giving the number of students in each grade in year t . For example, $s_{3,t}$ is the number of third grade children in year t . Let $A_t = [a_{1,t}, a_{2,t}, a_{3,t}, a_{4,t}, a_{5,t}, a_{6,t}]$ be the number of new students who join the system at each grade level at the beginning of school year t . In view of the way β was defined, the following assumption, about how students join the system, is justified.

Assumption 3. For all t , $a_{2,t} = a_{3,t} = a_{4,t} = a_{5,t} = a_{6,t} = 0$.

That is, new students only enter the first grade.

The following two equations are the basic equations of the system:

$$S_t = S_{t-1} T + A_t \text{ , and} \qquad (1)$$

$$G_t = \gamma s_{6,t} \text{ , where .} \qquad (V.2)$$

G_t = the number of graduates in year t and T is the transition matrix of the system, defined in the following way in terms of β and γ ,

$$T = \begin{bmatrix} \beta & \gamma & 0 & 0 & 0 & 0 \\ 0 & \beta & \gamma & 0 & 0 & 0 \\ 0 & 0 & \beta & \gamma & 0 & 0 \\ 0 & 0 & 0 & \beta & \gamma & 0 \\ 0 & 0 & 0 & 0 & \beta & \gamma \\ 0 & 0 & 0 & 0 & 0 & \beta \end{bmatrix}$$

The matrix equation V.1 is simply a compressed way of writing a series of equations of the form

$$s_{1,t} = \beta s_{1,t-1} + a_{1,t} ,$$

$$s_{2,t} = \beta s_{2,t-1} + \gamma s_{1,t-1} + a_{2,t} , \quad \text{etc.}$$

The latter equation, for example, states that the number of second grade students in year t is equal to the repetition rate times the number of second grade students in year $t-1$ plus the progression rate times the number of first grade students in year $t-1$ plus the number of new students who enter directly into grade 2 (this last is equal to zero by assumption 3).

In order to use available data to accurately estimate α , β , and γ for a developing country, a few more properties of the system must characterized. N_t will be the total number of students in the system at time t ; $N_t = s_{1,t} + s_{2,t} + s_{3,t} + s_{4,t} + s_{5,t} + s_{6,t}$. The system will be said to have a <u>steady-state input</u> I if I students enter first grade for the first time each year, i.e., $A_{1,t} = I$ for all t . The system will be said to have a <u>steadily growing input</u> at the rate r if $a_{1,t+1} = (1+r)\, a_{1,t}$, for all t . The <u>fraction of</u>

repeaters, to be labeled β^* , is the fraction of students in any one grade who were also in that same grade the preceding year. Notice that the fraction of repeaters is quite a different concept from the repetition rate, though they are obviously related; the exact relation between the two will be described below. The reason fraction of repeaters is introduced is because this variable is easier to observe and measure; the repetition rate may then be inferred from it.

A final concept to be introduced is that of efficiency.* The efficiency, E , of the system relates the number of graduates per year to the number of students in the system, if the system were to have a steady state input. Specifically, $E = 6Gt/N_t$; this is well defined since, if t is moderately large, G_t and N_t are independent of t with steady state input. As the number of graduates per year cannot exceed 1/6 the number of students in the system** -- since the elementary school lasts 6 years -- an efficiency of 1 indicates no drop-outs or repeaters. Even with a true efficiency of 1, however, the apparent value of E could be less than 1 if input is not steady state but is growing. This is because the graduates in year t were first graders six years previously when input was smaller. Thus true efficiency, E , will depend only on β and γ whereas the apparent efficiency will depend on β , γ , and r . For fixed β and γ (and hence fixed E) apparent efficiency decreases as r increases. For example, with 12.8 million students in 1969, and 1.114 million graduates, the Indonesian elementary education system had an apparent efficiency of .515. Since the number of students in the system had been growing at a rate of about 4.2% ($r = .042$) over the preceding years (Emerson [1968, p. 15]), the true efficiency of the system can be computed to be .590.

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*I use the term "efficiency" here solely in terms of relating inputs to outputs; this usage should not be confused with the common economic usage that relates choice of inputs to their prices.

**It is assumed that a negligibly small fraction of students "skip" grades.

Let me now state some properties of the system. For a <u>steady state input</u> of I per year the following hold:

$$s_{k,t} = \gamma^{k-1} I/(1-\beta)^k , \qquad (V.3)$$

$$\beta^* = \beta , \text{ and} \qquad (V.4)$$

$$E = [6\gamma^6/(1-\beta)^6] / \sum_{k=1}^{6} \gamma^{k-1}/(1-\beta)^k \qquad (V.5)$$

Equation V.3 gives the number of students at each grade level; the result can be established inductively and I will not prove it here. Equation V.4 states that the fraction of repeaters, β^* , is simply equal to β . This can be proved from V.3 in the following way. The fraction of repeaters in a grade will equal the number of students in that grade, $s_{k,t}$, minus the number in the grade who were promoted the previous year from the previous grade, $\gamma\, s_{k-1,\, t-1}$, all divided by the number in the grade. That is, $\beta^* = [\gamma^{k-1} I/(1-\beta)^k - \gamma^{k-1} I/(1-\beta)^{k-1}] / [\gamma^{k-1} I/(1-\beta)^k]$, and this is easily shown to equal β . Finally, equation V.5 follows directly from the definition of efficiency. The numerator is 6 times the number of graduates and follows from equations V.2 and V.3; the denominator is simply the number of students in the system and follows directly from equation V.3. Table V.1 shows several values of α and β for each of a number of values of E. (The table can as easily be expressed in terms of α and β as in terms of β and γ since $\alpha = 1-\beta-\gamma$.)

The preceding are properties of the system if the input is steady state. If the input is growing, I have been unable to prove similar results; however, the following was checked numerically in a number of cases, and appears to be true:

If input is growing at rate r , $\beta^* = \beta/(1 + r)$. (V.6)

This enables us to estimate β from the sometimes more readily available estimates of β^*

Table V.1: α, β Pairs Consistent with Several Values of E

α	β	E = .80	α	β	E = .65
.01	.16		.05	.18	
.02	.13		.06	.15	
.03	.10		.07	.12	
.04	.06		.08	.09	
.05	.03		.09	.06	

α	β	E = .55	α	β	E = .45
.07	.22		.10	.24	
.08	.19		.12	.18	
.09	.16		.14	.13	
.11	.11		.16	.08	
.13	.05		.18	.02	

The above, then, is the student flow or performance model that underlies the evaluation of the alternatives. In the remainder of Section V I describe how this model is used for this purpose.

B. Evaluation of Alternatives

The model developed in the preceding subsection takes its basic parameters -- α, β, and γ -- as given by the present structure of the school system. Progression from one grade to the next depends, presumably, on the student's convincing the teacher (or system) that he has reached a satisfactory level of educational attainment. Among those who fail to progress, the decision concerning whether the student is allowed to repeat, and whether he chooses to repeat will depend on his performance, his perception of what the school has to offer, and various economic and social factors. For these reasons, changing the effectiveness of instruction in the schools will change α, β, and γ. It would be ideal, of course, if for any instructional alternative a (see discussion immediately following equation II.3) one could assign values to α, β, and γ. It would then be possible to project the output of the school system as a function of time and the level of expenditures assigned to the system. The value of the research on effectiveness of alternative instructional technologies that was overviewed in Section IV is that it gives us some insight into how choice of technique affects flows in the system.* Nevertheless, we are not now in a position to do more than make informed estimates concerning the effects on α, β, and γ of introducing a new mix of instructional techniques.

Given our present state of understanding of the effectiveness of the various instructional technologies, I propose the following

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*Obtaining a clear understanding of these effects is made even more difficult by the fact that there are often changing policies concerning when to let a student progress.

evaluation methodology:

1. Treat as an exogenous parameter the rate of growth of expenditures on the, say, elementary school system. That is, a number of "reasonable" values of this parameter should be selected and the analysis below carried out for each to ascertain how varying the level of expenditure varies the level of outputs.

2. Project the costs of the various techniques of instruction into the future. A reasonable first estimate is that teacher salaries will grow at at least the rate of per capita GNP and that technology costs will remain constant; more refined estimates may be possible.

3. Using equation II.3, identify the combinations of numbers of students in the system and mixes of instructional technologies that are feasible given assumptions 1 and 2 concerning expenditures and costs. From this infinite number of possibilities, select a small number (5 to 20) that are representative of the overall range.

4. Using basic information on effectiveness of the sort mentioned in Section IV, make best estimates of the values of α, β, and γ that will result from each of the representative alternatives selected for examination.

5. For each alternative, insert the appropriate values of α, β, and γ into the model of the preceding subsection and use that model to project the number of graduates as a function of time, the number of dropouts (with various levels of schooling) as a function of time, and the participation rates* of various age groups as a function of time.

6. From the above projections, it will appear that certain alternatives are clearly dominated by others, but that there may be a number of alternatives that cannot be easily decided among. For example alternative i might yield higher levels of numbers of graduates and alternative j higher participation rates; choice

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*This relies on obtaining population projections for the relevant age group.

between them would have to be left to the value judgment of a decision-maker.

7. For the most attractive alternatives identified in Step 6, a sensitivity analysis should be performed to examine the effects of errors in estimating costs or the flow parameters. This sensitivity analysis combined with plans for development and implementation of the promising alternatives should be presented to the decision-maker for his assessment.

A detailed example of the above methodology may be found in Jamison [1971] where alternative conventional and radio technologies were examined for Indonesia. Appendix B of this paper summarizes that analysis; however, the original must be consulted for a detailed presentation of the methods. The purpose of this methodology is to examine the long term consequences of various alternatives for operating the schools. While not specifying any optimum choice of technologies, it does place before a decision-maker much more detailed information concerning the consequences of the more attractive alternatives he has to choose from.

C. Directions for Research

The title of this paper is "Notes on Cost-Effectiveness Analysis..." and I would like to stress that that is all that is intended at the present stage. There are many directions for further research; there will be progress in some of those directions in the remaining research to be done on this project, but much will remain to be done for some time.

On the cost side, it will be valuable to obtain a handbook of instructional technology costs and cost projections. These will often need to be expressed as equations such as II.4 rather than in terms of single numbers. It will also be of value to continue field research on what the costs of various educational technology projects actually have been and are planned to be.

On the effectiveness side there is no substitute for continuing longitudinal hard data analyses like those being done in El Salvador and Mexico. These need to be supplemented by similar analyses for other technologies (as well as for conventional alternatives as Carnoy has been doing in Puerto Rico). They also need to be supplemented by improved information on how the instructional effectiveness of the alternatives, as well as other factors, affect drop-out and repetition rates. This last line of research I consider to be highly important.

The basic evaluation model presented here needs further development. It is important to be able to summarize outcomes in a way or class of ways that would provide more insight to a decision-maker than the simple projections that were recommended here. The drop-out and repetition rates can be treated as being partially decision parameters as well as being partially determined by the choice of technique, and it is important that that possibility be incorporated into the model. A flexible version of the model, capable of working with data of varying degrees of refinement, needs to be put onto a computer in an interactive mode. This would allow planners to get a rapid and solid feel for the implications of the alternatives he is considering.

APPENDIX A: BENEFITS OF EDUCATION

In order to set the context for a cost-effectiveness analysis in education it is of value to restrict the range of output levels to be considered by analyzing the benefits of education. While a detailed survey of those benefits is beyond the scope of this paper, this appendix provides a short summary and references to the literature. Blaug [1970] provides a reasonably complete annotated bibliography and Klees [1972] has drafted a more extensive literature survey.

Education is typically viewed as having several benefits to individuals and, therefore, to society as a whole. Since wages may not reflect the marginal product of labor of a certain educational category the social benefits may differ from those to the individual.* Many benefits of education have defied any form of quantification and are reflected primarily in the high level of demand for education within most countries. In this brief survey I will first list a number of these unquantified benefits then I will briefly review some of the more quantitative results concerning the effect of education on economic growth, on industrial and agricultural productivity, and on wages.

A. Unquantified Benefits

The unquantified benefits include the following. (1) Education has a direct consumption value through its capacity to increase an

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*Wages may differ from marginal product due to distortions in factor markets, a frequent occurence, or due to the existence of "external economies" or "external diseconomies" in education. Economists have typically assumed the existence of external economies, i.e., that there are social benefits to an individual's education that go beyond benefits to the individual himself. See Blaug [1965] or Valzey [1962].

individual's enjoyment of life. (2) Education has a capacity to improve individual health (and hence, indirectly, economic productivity) by increasing receptiveness to improved nutritional and hygienic practices. (3) Educated individuals tend to be more receptive to birth control information. (4) Educated consumers are more capable of discriminating selection and use of consumer goods leading to less wastage through production of inferior products. The fact that the above benefits of education are not numerically specified in no way implies that they are unimportant. It simply means that an economic planner or decision-maker has less precise knowledge concerning these factors when he combines them with better measured effects to arrive at a final decision concerning what level of resources to devote to the educational sector. Rather more quantitative information is available concerning the effect of education on aggregate economic growth, the earnings of the urban labor force, and on agricultural productivity, and that evidence will be reviewed below. But the reader should be constantly aware that there is considerable inaccuracy in much of the underlying data reported below, and that often the data available is subject to a variety of interpretations.

B. Education and Aggregate Production

In two now classic studies Denison [1962, 1967] attempted to account for economic growth in the United States (The Sources of Economic Growth in the United States and the Alternatives Before Us) and Western Europe (Why Growth Rates Differ). His basic methodology was to specify and to estimate a functional relation (aggregate production function) between output and measures of capital and labor input. Given such a production function one can attempt to account for changes in output from changes in the capital and labor inputs; this attempt left a "residual" of output unaccounted for. However, one can categorize the labor force by level of educational attainment and from an index of labor quality by weighting the number

of laborers in each category by the average wage of that category. Changes in this index of labor quality can explain about one third of the residual -- see Griliches and Jorgenson [1967] or Griliches [1970]. A growth in the labor quality index of .8% per year in the United States contributed about .6% per year of growth in GNP in the period 1940-1967.

Theoretically one could divide the value of increased growth in a year by the annual cost of education to obtain a rate of return to education (it would be about 10% in the U.S., by this measure). But for a variety of reasons the specific quantitative result would be of little value. First, this measure could be widely different for developing countries and the data to determine it are unavailable. Second, relative wages do not necessarily reflect the relative marginal products of different types of education, as was pointed out before. Third, the educational system is not the only determinant of the labor quality mix. Even if, for these reasons, the quantitative results are of little practical interest, it is nonetheless significant that these studies consistently indicate that the quality of the labor force accounts for an important amount of economic growth in the developed countries.

C. Education and Worker Productivity

In the preceding comments, I reviewed evidence indicating that one important determinant of aggregate productivity is the average level of education within a country. At this point I will turn to evidence from a much lower level of aggregation; this evidence relates agricultural and industrial productivity in the United States to worker education.

Much of the information concerning the effects of education on manufacturing and agricultural productivity in the United States appears in a series of econometric studies undertaken by Z. Griliches. Many of the important results of these studies are summarized in Table 4

of Griliches [1970], and, with minor modification, that table is reproduced here as Table A.1. For example, in row b of line 1 of the table one sees that a 10% increase in the number of workers would yield a 5.2% increase in output and a 10% increase in educational level would yield a 4.3% increase in output.* The ratios of the coefficients to their standard errors (in parentheses below them) indicate the coefficients to be highly significant. Similar remarks apply to the other three lines in the table. Once again we see that education has a substantial impact on output, here at a much less aggregated level.

While showing a direct link between education and worker productivity, these results again have limited policy implications for developing countries. They are from the United States, they fail to examine costs, and they fail to take into sufficient account the possibility that higher productivity is causing higher levels of education rather than the other way around. Thus even with these disaggregated studies we are unable to come to specific, quantitative estimates of the benefits of education in increasing productivity. Nevertheless, other authors, dealing with problems of developing countries, have reached conclusions that are consistent with Griliches' findings in the United States that higher levels of education lead to higher levels of agricultural productivity. For example, T. Schultz [1964] has stressed the critical role of education in modernizing traditional agriculture but V. L. Griffiths [1968] argues from practical experience that education can be only one of many factors if there is to be success.

D. Education and Urban Wage Level

The studies described above directly examine the effects of average levels of education on output. A much more c... on method of

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*This follows because the variables in the equation are expressed as logarithms of the original variables.

Table A.1: Education and Skill Variables in Production Function Studies[a,b]

Industry, Unit of Observation, Period and Sample Size		Labor Coefficient	Education or Skill Variable Coefficient	R^2
1. U.S. Agriculture, 68 Regions, 1949	a.	.45		.977
		(.07)		
	b.	.52	.43	.979
		(.08)	(.18)	
2. U.S. Agriculture, 39 "states," 1949-54-59	a.	.43		.980
		(.05)		
	b.	.51	.41	
		(.06)	(.16)	.981
3. U.S. Manufacturing, states and two-digit industries, N = 417, 1958	a.	.67		.547
		(.01)		
	b.	.69	.95	.665
		(.01)	(.07)	
4. U.S. Manufacturing, states and two-digit industries, N = 783, 1954-57-63	a.	.71		.623
		(.01)		
	b.	.75	.96	.757
		(.01)	(.06)	
	c.	.85	.56	.884
		(.01)	(.16)	

[a]All the variables (except for state industry, or time dummy variables) are in the form of logarithms of original values. The numbers in parentheses are the calculated standard errors of the respective coefficients.

Table A.1 (continued)

[b]The source of this table is Griliches [1970], Table 4.

Notes:

1. Dependent variable: sales, home consumption, inventory change, and government payments. Labor: full-time equivalent man-years. "Education" - average education of the rural farm population weighted by average income by education class-weights for the U.S. as a whole, per man. Other variables included in the regression: livestock inputs, machinery inputs, land, buildings, and other current inputs. All variables (except education) are averaged per commercial farm in a region.

2. Dependent variable: same as in (1) but deflated for price change. Labor: total man-days, with downward adjustments for operators over 65 and unpaid family workers. Education: similar to (1). Other variables: Machinery inputs, Land and buildings, Fertilizer, "Other," and time dummies. All of the variables (except education and the time dummies) are per farm state averages.

3. Dependent variable: Value added per man-hour. Labor: total man-hours. Skill: Occupational mix-annual average income predicted for the particular labor force on the basis of its occupational mix and national average incomes by occupation. Other variable: Capital Services. All variables in per-establishment units.

4. Dependent, labor, and skill variables same as above. Other variables: a. and b. Capital based on estimated gross-book-value of fixed assetts; c. also includes 18 Industry and 20 regional dummy variables.

analysis has been an indirect one that proceeds by assuming that an individual's wages are equal to his marginal productivity. If so, one can assess the economic contribution of education by examining the wage differences between individuals with one level of education and those with another. If one has a cost estimate of the incremental education (including the earnings foregone by the student while in school), and of the wage differences at various points in time over an individual's life, one can compute an internal rate of return* to investment in education. Details of these techniques are described in a very straightforward fashion by Woodhall [1970] and early examples may be found in Hansen [1963] and Blaug [1965]. Most studies are based on urban rather than rural surveys of wages.

Carnoy [1972] has recently drawn from many studies to compile a list of estimated rates of return to primary, secondary, and university education in 27 countries. His list, with detailed references to the original sources, is included as Table A.2. In a forthcoming book G. Psacharopoulos [1972] surveys and critically reviews rate of return data from 32 countries. The average unadjusted social rates of return to education in the less-developed countries surveyed by Carnoy are 17.4% for primary, 15.2% for secondary, and 12.7% for university. Clearly, however, many factors beside education may contribute to the observed fact that individuals with more education have higher incomes. Differing native ability and differing socio-

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*The internal rate of return of an investment is defined in terms of the time streams of costs and benefits resulting from it. Assume that an investment has no benefits or costs after n years and that in year t the cost of the investment is C_t and the benefit B_t. If the interest rate is r per cent per year, the <u>present value</u> of the investment is given by $\sum_{t=0}^{n} (B_t - C_t)/(1 + r)^t$. The value of r that makes the present value zero is the internal rate of return; the higher the internal rate of return, the more rapidly do the investment's benefits repay its costs.

Table A.2: Rates of Return to Schooling*

Social Rates of Return to Schooling, Enrollment Rates, Gross Domestic Product per Capita, and Economic Growth Rates, by Country for Various Years, Primary, Secondary and University Levels of Schooling

Country	(1) Year	(2) Primary Rate of Return	(3) Primary Enrollment Rate	(4) Sec. Rate of Return	(5) Sec. Enrollment Rate	(6) Univ. Rate of Return	(7) Univ. Enrollment Rate	(8) GDP/ Capita	(9) Economic Growth Rate
United States	1959	-	-	14[a]	82	10[a]	1576	2361	0.4
Canada	1961	-	-	14[a]	56	15[a]	725	1774	0.6
Puerto Rico	1960	21	70	22	46	16	1186	661	4.6
Mexico	1963	25	50	17	12	23	337	374	1.6
Venezuela	1957	82[b]	42	17	10	23	230	730	3.8
Colombia	1965	40	56	24	19	8	307	320	1.4
Chile	1959	12	68	12	23	9[c]	364	365	0.8
Brazil	1962	11	46	17	12	14	182	261	4.0
S. Korea	1967	12	66	9	33	5	760	146	6.6
Israel	1958	16	63	7	36	7	625	704	4.4
India	1960	20	20	13	31	13	281	73	1.8
Malaysia[d]	1967	9	56	12	28	11	142	280	2.8
Phillipines	1966	8	56	21	34	11	1931	250	1.4
Japan	1961	-	-	7	79	6	510	464	5.8
Ghana	1967	18	35	11	34	16	70	233	-0.8
Kenya	1968	22	48	20	6	9	59	118	4.4
Uganda[e]	1965	66	32	50	7	12	19	84	1.4
Zambia	1960	12	28	-	-	-	-	144	4.8

*This Table was compiled by Carnoy [1972] and appears as Table 1 of that paper.

Great Britain	1966	-	-	5	96	8	382	1660	2.4
Germany	1964	-	-	-	-	5	396	1420	3.5
Denmark	1964	-	-	-	-	8	545	1651	4.2
Norway	1966	-	-	7	69	5	375	1831	4.2
Sweden	1967	-	-	10	44	9	647	2500	4.0
Belgium	1967	-	-	-	-	9	384	1777	3.4
Netherlands	1965	-	-	6	91	6	902	1490	3.2
Greece	1964	-	-	3	38	8	374	478	3.8
New Zealand[f]	1966	-	-	20	71	13	1005	1931	3.0

Sources

Columns (1), (2), (4), and (6)--general source: George Psacharapoulos and K. Hinchliffe, "Rates of Return: International Comparison," London School of Economics, Higher Education Research Unit, 1970 (mimeo).

United States: Giora Hanoch, "An Economic Analysis of Earnings and Schooling," Journal of Human Resources, Vol. II, No. 3 (Summer, 1967) pp. 310-329.

Canada: J. R. Podoluk, Earnings and Education, Canada Dominion Bureau of Statistics, 1965.

Puerto Rico: Martin Carnoy, "The Rate of Return to Schooling and the Increase in Human Resources in Puerto Rico," Stanford University, 1970 (mimeo).

Mexico, Venezuela and Chile: Martin Carnoy, "Rates of Return to Schooling in Latin America," Journal of Human Resources, Vol. II, No. 3, Summer, 1967. For Chilean rates shown here, see footnote 11 adjusting rates shown in Table 7 of that article.

Colombia: H. Selowsky, "The Effect of Unemployment and Growth on the Rate of Return to Education: The Case of Colombia," Harvard University, Economic Development Report No. 116, November, 1968.

Brazil: S. A. Hewlett, "Rate of Return Analysis: Role in Determining the Significance of Education in the Development of Brazil," 1970 (mimeo).

South Korea: Kim Kwang Suk, "Rates of Return on Education in Korea," USAID, 1968 (mimeo).

Israel: Ruth Klinov-Malul, "The Profitability of Investment in Education in Israel," The Maurice Falk Institute for Economic Research in Israel, Jerusalem, April, 1966.

India: M. Blaug, R. Layard and M. Woodhall, The Causes of Graduate Unemployment in India (London: The Penguin Press, 1969).

Malaysia: O. D. Hoerr, Development Advisory Service, Harvard University (unpublished), reported in Psacharapoulos and Hinchliffe, op. cit.

Phillipines: D. Devoretz, "Alternative Planning Models for Phillipine Educational Investment," The Phillipine Economic Journal, No. 16 (1969).

Japan: M. J. Brown, "Mass Elites at the Threshold of the Seventies," Comparative Education (London), forthcoming.

Ghana: K. Hinchliffe, "Educational Planning Techniques for Developing Countries with Special Reference to Ghana and Nigeria," unpublished M.Phil. dissertation, U. of Leicester, 1969.

Kenya: Hans Heinrich Thias and Martin Carnoy, Cost-Benefit Analysis in Education: A Case Study on Kenya. Economic Department, IBRD, Nov., 1969 (EC-173).

Uganda: John Smyth and Nicholas Bennett, "Rates of Return on Investment in Education: A Tool for Short-term Educational Planning Illustrated with Ugandan Data," The World Yearbook of Education (London; Evans Brothers, 1967).

Zambia (Northern Rhodesia): R. E. Baldwin, Economic Development and Export Growth (Berkeley; U. of California Press, 1966).

The following European and New Zealand rates are all reported in Psacharapoulos and Hinchliffe, op. cit.:

Great Britain: L. Magler and R. Layard, "How Profitable is Engineering Education?" Higher Education Review, Vol. 2, No. 2 (Spring, 1970).

Germany: Klaus-Dieter Schmidt and Peter Baumgarten, "Berufliche Ausbildung und Einkommen," in A. E. Ott (ed.), Theoretische und Empirische Beiträge zur Wirtschaftsforschung, Tübingen, Mohr, 1967.

Denmark: N. B. Hansen, "Uddannelsesinvesteringernes Rentabilitet," National/Konomisk Tidsskrift, No. 5-6, Copenhagen, 1969.

Norway: J. Aarrestad, On Lønnsheten av å Investere i Utdanning i Norge, Norges Handelsk/yskole Samfunns/konomisk Institutt, Bergen, 1967.

Sweden: Leif Magnuson, Department of Economics, University of Stockholm (unpublished).

Belgium: W. Deseeyere, "Een Onderwijsmodel voor Belgie, Deel 2," Katholicke Universitaet te Leuven, Centrum voor Economische Studien, 1969 (mimeo).

Netherlands: P. de Wolff and R. Ruiter, De Economie vay he Onderwijs (Gravenhage: Montinus Nijhoff, 1968).

Greece: H. Leibenstein, "Rates of Return to Education in Greece," Harvard University, Economic Development Report No. 94, September, 1967.

New Zealand: B. J. Ogilvy, "Investment in New Zealand Education and its Economic Value, 1951-1966," Unpublished M.Com. dissertation, Universit of Auckland, 1968.

Column (3): UNESCO, Statistical Yearbook, 1966 and 1967. Enrollment rates taken from Table 2.5 for year five years previous to column (1) year. The rationale for this is that the average person with primary school training is assumed not to enter the labor force for five years after he leaves primary school. So the effect of enrollment rates on rate of return would be lagged by at least five years. The enrollment rate for the column (1) minus 5 years is corrected to a six year length primary school program, so that all ratios represent a six year equivalent primary enrollment as a percentage of 5-14 year-olds in the country. Length of primary school in each country is taken from Table 2.1.

Column (5): Ibid. General secondary education only. The enrollment rate is taken for year three years previous to column (1) year. Enrollment rate is corrected to a four year length secondary school program, so that all ratios represent a four year equivalent secondary enrollment as a percentage of 15-19 year-olds in the country.

Column (7): Ibid. University enrollment is estimated as the number of universit students perpopulation 15 years old and older. The enrollment rates are taken from Table 2.10. The correction for population 15 years old and older is based on population data from United Nations, Demographic Yearbook, 1960-1969.

Column (8): George Psacharapoulos, "The Economic Returns to Higher Education in Twenty-five Countries," London School of Economics, Higher Education Unit, 1970, Table 1.

Column (9): United Nations, Statistical Yearbook, 1968. Economic growth rate is taken as the average percentage change in gross domestic product per capita in the period t-5 to t, where t is the year shown in Column (1).

Notes:

a. The rates for the U.S. and Canada as reported are private rates. The rates as shown here have been lowered in accordance with the difference between private and social rates as estimated in W. L. Hansen, "Total and Private Returns to Investment in Schooling," Journal of Political Economy, Vol. 71, No. 2 (April, 1963), pp. 128-40.

b. The 82 percent rate represents the return between illiterates and six years of schooling. Income foregone is assumed to be zero. Both facts imply that the rate is seriously overestimated. It has been omitted from the regression estimates below.

c. The rate as reported in Hamberger and Selowsky is 12 percent, but as shown in Carnoy, op. cit., 1967 this is an overestimate. The 9 percent rate is approximate.

d. Rates shown here are underestimates of unadjusted rates, since they have been corrected for non-schooling factors.

e. Rates for Uganda are seriously overestimated, since they are based on differences between average incomes of employees with different amounts of schooling. This assumes that income differences are constant over lifetime. The Ugandan rates are therefore omitted from the regression estimates.

f. Ogilvy uses an alpha-coefficient of 0.5, but he probably overestimates unadjusted rates, since he also uses starting salaries of government employees as his base for estimates.

economic status are perhaps the two most important of these. For this reason it is standard in this literature to apply an "adjustment factor" to the raw rates of return described above. Carnoy uses adjustment factors of .4 for primary, .8 for secondary, and .9 for university for less-developed countries; these lead to adjusted social rates of return of 7%, 12.2%, and 11.4% respectively.

While these rates of return are not dramatically high they do indicate, particularly if consumption benefits are considered, that investment in education has important economic benefits. Carnoy stresses that the computed rates of return are quite sensitive to the estimated costs; it would then follow that reduction in cost through improved efficiency could markedly increase the rate of return to education. It is for this reason that improving efficiency must be a central goal of educational planners.

E. Manpower Planning

In the three preceding subsections I have surveyed attempts to measure the benefits of education, by direct or indirect studies of its past impact on productivity. The term "manpower planning" connotes a rather different way of assessing the benefits of education and, as it is a technique that has been occasionally used by educational planners, I should mention it here. A clear overview of the technique may be found in Parnes [1964] but the technique consists essentially of forecasting into the future the "requirements" the economy will have for each category of educated labor. The benefits of having an educational system accrue to its capacity to meet these requirements.

The manpower forecasting is done by: (1) obtaining estimates of the number of laborers of each level of education required per unit output in each economic sector, (2) forecasting the level of output of each sector at time t, (3) summing across sectors to obtain the total requirement for each educational category of labor, and (4) computing

how many new laborers of each educational level must be added to the labor force between now and time t to meet these requirements. It is the task of the educational system to meet these requirements. While the above is an oversimplification of the manpower planning approach, even more sophisticated versions of it tend to share two important flaws. The first is that requirements are set without regard to costs; this could, of course, lead to severe misallocation of resources. Second, this approach fails to allow for a potentially high elasticity of substitution among laborers of varying skill categories; Bowles [1969, Chapter III] argues that this elasticity is, in fact, quite high.

A series of case studies of the usefulness of manpower planning has recently been undertaken -- see Ahamad, Blaug, et. al. [1972] -- and the general conclusion was that they were of little value.

F. Conclusion

In concluding this brief overview of studies of the benefits of education, two central points emerge. First, studies of many types in many countries consistently indicate that education contributes to increased productivity of the labor force. Second, we have only an imprecise estimate of this effect, particularly for developing countries, since only the rate of return studies dealt with data from those countries and those studies have many shortcomings from a policy point of view.

APPENDIX B: AN EXAMPLE COST-EFFECTIVENESS ANALYSIS: ELEMENTARY EDUCATION IN INDONESIA*

In a recent report prepared for UNESCO -- Jamison [1971] -- I examined the potential role of educational technology in alleviating financial and quality problems in elementary education in Indonesia. My purpose in this Appendix is to illustrate the methodological framework of the present paper by summarizing the results of that report. Some of the cost estimates used here have been made out of date by R. Daroesman [1971, 1972] in a recent study of the financing of education in Indonesia. However, the more refined cost estimates she makes available in her papers are, in most cases, rather close to the crude estimates I use and thus many of the results I shall describe are consistent with the numbers she obtains.

The first section of this Appendix provides projections of elementary school graduates and participation rates for various assumptions about the rate of growth of budgets and costs, assuming no change in the structure of the elementary system. The second section outlines alternatives available to Indonesian educational planners and concludes that extensive use of radio appears quite attractive. The final section discusses the cost and probable performance of radio.

A. Projection of Present System

In order to place a discussion of alternatives into perspective,

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it is useful to project the performance of the present system into the future. Available data can be used to compute an annual drop-out rate of about 10% and an annual repetition rate slightly over 10%; from these numbers I have computed numbers of graduates per year as a function of available budget for elementary schools and per student costs. Assuming an average class size of 35 students, an average teacher salary (in 1968) of Rp. 57,300 per year, an average annual cost of classroom use of Rp. 23,000, and that on the average 1.5 classes use each classroom, the per student annual cost in 1968 was Rp. 2070.* (This compares reasonably well with Daroesman's 1971 survey data estimate of Rp. 2583; much of the difference comes from her estimate of Rp. 66,000 as the annual cost of a teacher.) The total expenditure on elementary education in 1968 is the product of Rp. 2070 and the enrollment of approximately 12,000,000 students -- i.e., about Rp. 24.8 billion. Table B.1 shows the number of graduates as a function of time starting with these 1968 base numbers and assuming no changes in the drop-out and repetition rates. (The growth rate of effective expenditures is

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*All references to rupiahs in this note refer to 1970 rupiahs; there are approximately 340 rupiahs per dollar. Class size and classroom use estimates are based on P. Slors, "Some Bottlenecks in Indonesia's Educational System, with a View on its Future," Unpublished BPP Report, January 1971. Daroesman uses higher estimates -- 40 to 1 for the student to teacher ratio (Part I, p. 84) and more intensive shifting to obtain high classroom utilization (Part I, p. 91).

TABLE B.1: Numbers of Graduates of Elementary School, Present System[a]

Year	Growth Rate of Effective Expenditures[b]			
	-3%	0%	3%	6%
1970	1.130	1.114	1.099	1.085
1974	1.288	1.280	1.270	1.255
1978	1.148	1.280	1.420	1.567
1982	1.019	1.280	1.594	1.971

[a]Figures in the table are expressed in millions.

[b]The rate of growth of effective expenditures is defined to be the rate of growth of real expenditures minus the rate of growth of costs. These numbers are computed by the methods of Section V.A.

the difference between the growth rate of expenditures in real terms less the growth of costs in real terms.) Daroesman estimates that the real growth of elementary teacher salaries (the bulk of costs) will be 3.5%; thus it would take a 6.5% rate of increase in overall expenditures to produce a 3% rate for effective expenditures.

Knowing the level of elementary school enrollment and the number of children aged 7 to 12, one can compute a "gross" participation rate for the system by dividing the second into the first. However, many of the individuals enrolled may actually be over 12 so a more appropriate measure is the number of students enrolled net of the number over 12; this number divided by the total number of children aged 7-12 was defined as the "real" participation rate. The real participation rate can be computed from a knowledge of the drop-out rate, repetition rate, and rate of growth of enroolment; Table B.2 shows projections of the real participation rate as a function of the growth rate of effective expenditures.

TABLE B.2: Real Participation Rates as a Function of Time

Year	Growth Rate of Effective Expenditures[a]			
	-3%	0%	3%	6%
1970	.577	.595	.613	.631
1974	.454	.529	.613	.708
1978	.358	.470	.614	.795
1982	.282	.418	.614	.892

[a]The rate of growth of effective expenditures is defined to be the rate of growth of real expenditures minus the rate of growth of costs.

It is also possible, though slightly more complicated, to iteratively solve for the level of expenditures required to maintain the 1969 real participation rate of about 61% as a function of the rate of growth of real costs; if, for example, real costs increase at a 4% annual rate the real expenditures in 1982 will need to be more than double those for 1971 to simply prevent a decline in the participation rate. It is this rather pessimistic conclusion that leads us to analyze alternatives to the present system.

B. Alternatives to the Present System

If a number of different techniques for providing elementary education exist, then at any given time a certain fraction (perhaps zero) of Indonesian students will be using each technique. An alternative at a point in time is a specification of the fraction of students using each technique at that time, and planning consists of comparing and evaluating various time streams of alternatives. In this section I will analyze a variety of alternatives to the present technique for

elementary education and will leave it as understood that not only the techniques presented but any mixes of them are possible alternatives; the basic conventional and technological alternatives to be analyzed are described in Section II.A. The analysis begins by eliminating alternatives that appear clearly undesirable for Indonesia at the present time.

Elimination of Less Desirable Technological Alternatives. Since six technologies were listed in II.A, and five alternative ways of using them, there are a total of thirty broad "technological alternatives". Most of these are unattractive, however, and this subsection sharply reduces this rather extensive list. A basic source of information on the performance of the new media, and to a lesser extent their relative costs, is Learning from Television: What the Research Says by G. Chu and W. Schramm [1968]. Chapter VI of that volume deals with studies of media other than television. Somewhat more detailed cost studies may be found, for past projects, in Schramm, Coombs, Kahner, and Lyle [1967] and in its accompanying 3 volumes of case studies. My analysis at this point will draw heavily on these previous findings.

Chu and Schramm record hundreds of instances where television teaches as well or better than a well trained classroom teacher, in addition to a number of instances where it fails to do as well. Television appears to work relatively better for elementary students than for older ones and there seems to be no doubt that television could effectively teach in the elementary schools of Indonesia. However, television is expensive -- perhaps five times as expensive as radio (Schramm, et. al., p. 131) -- and, except where moving pictures are essential, radio appears to teach about as well. For reason of its much higher cost than radio, I conclude that television is an unviable alternative for primary education in Indonesia at the present time. However, it does appear that transmission costs can be made much lower than they are today -- see Bourett [1971] -- and there may come a time when sufficient funds are available for Indonesian elementary education to include selective use of television. It is also possible that more

sophisticated future work on the comparative effectiveness of different media for different tasks will define areas where television is more cost effective.

Blackboard television is a technique under development by Dr. Iskandar Alisjahbana of the Bandung Technological Institute (I.T.B.) with colleagues from Holland. Its major attraction is that its video signal can be transmitted over a voice grade circuit; a disadvantage is that it requires a modification to an ordinary television set that may be costly. As blackboard television is still under development, and its production costs remain uncertain, it cannot be considered an active contender for operational use for the next 4 to 6 years. It appears sufficiently promising, nonetheless, that further development at I.T.B. should be encouraged.

For many purposes, classroom controlled audio-visual media appear potentially attractive. Films teach about as well as television and, though there is less evidence for this, it is reasonable to conjecture that cassette tapes would teach as well as radio. The critical point for comparing these alternatives to broadcast alternatives appears to be the question of economies of scale. Chu and Schramm cite a study of the French Bureau d'Etudes ORTF indicating that over the air transmission of audio was less costly than disc distribution for audiences over about 3000. Presumably the break even number in Indonesia would be considerably less since, due to poorer transportation in Indonesia than in France, each location would require considerably larger inventories of recorded material, which would in turn sharply increase costs. Classroom audio-visual media are discussed at greater length in M. Jamison [1967] and may have a potentially valuable role to play for higher levels of education in urban areas. However, the economies of scale issue would seem to rule them out for mass use at the elementary level.

Fourth on the list of alternative technologies to be considered is radio. In terms of both cost and performance for large audiences radio is attractive. The next section contains more detailed performance information concerning radio as well as cost equations for its use under several sets of assumptions. Chu and Schramm cite a number of

studies that indicate radio can teach about as well as television or as a well trained classroom teacher. More recent surveys of the literature concerning instructional radio were referred to in Section IV.

Jamison, Fletcher, Suppes, and Atkinson [1971] present evidence that computer assisted instruction (CAI) is becoming an attractive educational alternative for developed countries, but the cost figures in their paper completely rule out CAI for operational use in Indonesia in the foreseeable future. Computer managed instruction (CMI) is considerably less expensive and Jamison and Ball [1971] have suggested that it is potentially capable of being distributed by satellite at night to quite dispersed and remote areas. Nonetheless, per student annual costs of a minimum of $10 to $15 per subject matter indicate that CMI is not yet to the point where it could be seriously considered for operational use in Indonesia.

In a review of the literature on programmed instruction, Schramm [1964] concludes that programmed self instruction can teach effectively; research available to him at that time was almost entirely conducted in developed countries. Roebuck [1969] reports on an experiment involving programmed instruction that took place in Nigeria. He concludes that programmed texts were successful teaching devices with some students, but that effective usage depended on the presence of a regular teacher and that coordination of students at different points caused considerable administrative difficulty. I have no information available concerning the cost of programmed instruction, although fairly good estimates of part of the cost could be made if the number of pages covered per day were known. I would conclude that programmed instruction is potentially somewhat attractive but probably costly and difficult to impremeut on a wide scale. Partially for lack of data and partially because it seems unlikely to be instructionally superior to radio, programmed instruction was not considered further in the UNESCO Report. More consideration should probably be given this possibility, however.

I will now turn to consideration of alternative ways of using the technologies. The first two that were listed -- enrichment and

complete replacement of the teacher -- will be considered only briefly. Rather than providing a serious alternative to the present system, enrichment would tend to provide only a minor change, though potentially a somewhat costly one. Complete replacement of the teacher falls at the other end of the scale. The possibility that there would be no need for individuals in the classroom with approximately the level of training of present day primary teachers would seem to be both pedagogically and politically improbable.

Substantial supplementation of the classroom teacher, on the other hand, seems entirely feasible. The medium could take most of the burden of instruction while the teacher would assist individual students, grade papers, and acquire more training herself. For this last reason little real difference exists between this alternative and the last use listed, substantial supplementation plus teacher training. If a medium is used for substantial supplementation, increasing class size or reducing the number of hours in the student's school week would lead to reductions in teacher requirements. This would be true even though the teacher remains in the classroom during all broadcasts, both to supervise the children and for teacher training.

A final use of the medium would be for the sole purpose of improving teacher quality and only through that means influencing student performance. This possibility has been analysed for Indonesia in a BPP study by Miarso that compares use of radio to conventional means for upgrading teachers; he concludes that radio would be considerably less costly.

This completes the initial analysis of the technological alternatives. Radio emerges as the most attractive technology and the most attractive use appears to be for teacher training (to be labeled Radio 1) or for substantial supplementation of the teacher plus teacher training. Four explicit ways of using radio for substantial supplementation were analyzed in my report to UNESCO and these are labeled Radio 2 through Radio 5. Table B.3 describes these 5 uses of radio in more detail; while these uses clearly represent only a few of the logical possibilities, I consider them representative of the major alternatives. Before examining their costs we will return to the conventional alternatives.

Table B.3: Uses for Radio in Primary Education[a]

Label	Description
Radio 1	This alternative is described in detail in Miarso [1970] and involves short term (1 to 3 week) workshops for teacher upgrading. Workshops would use radio and/or recorded audio instruction.
Radio 2	This alternative would leave unchanged all aspects of the present system except that in one subject matter there would be a 20-30 minute daily broadcast at each grade level. The purpose of this broadcast would be to substantially supplement the teacher's presentation in that subject, and to help teach the teacher.
Radio 3	This would be the same as Radio 2 except that there would be daily broadcasts in two subject matters instead of one.
Radio 4	This would be the same as Radio 2 except that the school day would be shortened to four hours for all students to allow for double shifts. The resulting increase in the ratio of the number of students in the system to the number of teachers would help cover the cost of introducing radio.
Radio 5	This would be the same as Radio 4 except that there would be daily broadcasts in two subject matters instead of one.

[a]This table describes the radio alternatives whose cost and performance are analyzed in more detail in the text. Clearly these are not the only ways to use radio; they are, in fact, somewhat conservative in that it is at least conceivable that many more subject matters could be taught. Also, radio could be introduced with much more radical increases (or changes) in average student to teacher ratio than considered here. The purpose of detailed examination of these particular radio alternatives is to ascertain the consequences of promising, and feasible, steps in several different directions.

Less Desirable Conventional Alternatives. The various conventional alternatives appear implicitly in equation II.2. The first variable to consider is that of teacher quality, the importance of which has been stressed by Beeby [1966]. Unfortunately, using conventional means to significantly change the average quality of so large a teaching force as Indonesia's would be enormously costly, take much time (Beeby measures it in generations), and might oblige many teachers to leave their posts unfilled for significant periods. Therefore less significant changes in teacher quality were examined (by Miarso) assuming both conventional retraining and Radio 1.

The second conventional variable is class size. This variable is critically significant due to its impact on cost. A number of studies examining the impact of class size on student performance seem to indicate little impact of these variable on student achievement; see Section IV.

The third conventional variable is number of hours in the student's school week. This, along with class size, determines the average student to teacher ratio and is equally significant in terms of costs. I was able to find less evidence concerning the impact of this variable on performance, but Bennett [1971] argues "... one hard fact to be borne in mind is that very few people in developing rural areas in Africa (and probably elsewhere too) work a full day anyway. This is partly due to tradition but, more significantly, to worms, dysentery and malnutrition. ...there is little objective evidence to show whether much extra is taught in insisting that the underfed children remain in their classrooms six hours a day instead of three or four hours."

A final variable is that of classroom utilization. In order to minimize per student costs it is clearly desirable to increase to the maximum possible the number of hours per day a classroom is used. The feasibility of doing this depends very much on the number of hours per week that classes meet. If the average is four and a half hours per day or less, double shifting is probably possible; otherwise, it might be difficult. As Daroesman [1971] has indicated, classroom

utilization is already good in Indonesia — Slors [1971] indicates 1.5 classes per classroom — but it would seem desirable to push this closer to 2. The cost implications of this, which are included in the analysis of Radio 4 and Radio 5, are not large but are nonetheless significant, and become more so if class buildings only last 15 or 20 years instead of the sometimes assumed 50.

The above consideration of conventional alternatives suggests the possibility of improving quality through radio while perhaps financing the radio at least partially by higher aggregate student to teacher ratios or rates of classroom usage. We turn to these possibilities in the next section.

C. Cost and Performance of Educational Radio

The preceding section concluded that radio appears to be the most attractive technological alternative for Indonesia at the present time. In this subsection I examine further the cost and probable performance of radio in an Indonesian setting.

Component Costs of Radio. This analysis will deal with five basic components of the cost of providing educational radio -- programming costs, book costs, receiver costs, transmitter costs, and teacher training costs. The purpose of the analysis is not to further refine engineering cost estimates but to combine generally available, though occasionally slightly inaccurate, numbers into a meaningful picture of total cost.

My programming cost estimates come from a recent, highly detailed proposal prepared by Stanford University's Institute for Mathematical Studies in the Social Sciences to the United States Agency for International Development. (By programming cost I mean the total cost of preparing the audio tapes for broadcast plus the cost of writing the accompanying printed material.) The purpose of the proposal was, among other things, to program curriculum for teaching arithmetic by

radio in a developing country for grades 1 through 6. The cost was high in order to allow carefully controlled curriculum development based on continual analysis of student response to the instruction. A cost of $75,000 per course year (or $300,000 for the six years) emerges as the best estimate from that proposal, and that is the number I shall use here. It should be stressed, however, that this cost estimate is a very conservative one indeed; Radio Republic Indonesia, for example, currently estimates the cost of its educational programming to be about $60. per hour, or less than $10,000 for a year long course segment. Much of the difference probably lies in the iterative development and evaluation cycle proposed by the Stanford group. In order to assure quality programming for mass usage, the development effort is likely worthwhile -- and it is also a mechanism for gradual implementation. Given this development effort, however, the program will be assumed to last 12 years.

The second component of cost to be considered is that of printed material for the students. For about $.0033 per page, technology now in use in Indonesia can produce books with a 3 year lifetime under moderate student use. New techniques using semiplasticized paper are becoming available that should extend lifetime at this level of usage to 5 or 10 years and perhaps slightly reduce costs. In this report the expected costs are assumed to be $.0025 per page with a 5 year lifetime.* With this estimate, as with all the component cost estimates, the cost equations will also be derived for a pessimistic case assuming 1.5 times these costs and an optimistic case assuming .65 times these costs.

The next cost area is that of receivers. Typical prices for commercial receivers at an electronics store in Jogjakarta in May 1971

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*To give an idea of what is possible in this area, I purchased the two volumes of Paul Samuelson's Collected Scientific Papers in Taipei at a commercial bookstore for $2.50. These were hard bound, very legible, and total over 1800 pages. This is $.0014 per page. An important aspect of the cost of books and printed materials will be that of distributing them to widely scattered rural classrooms, and this point needs further study. I have made allowance for that cost by estimating a somewhat high cost per printed page.

ranged from Rp. 3000 for a Golinda Junior III operating between 40 and 140 meters to Rp. 13,300 for a portable Philips 16RL377 with three separate short wave bands. As it is extremely difficult to separate costs from price when tariffs separate markets from the international economy, I simply use $20 as a representative international price for an excellent battery operated receiver.*

The next cost component is that of transmitters. Detailed cost estimates here must await the decisions concerning medium wave versus short wave versus FM as well as the results of more detailed transmission studies. Nevertheless it is possible to place an approximate upper bound on these costs by using a cost of $5000 for a low power, one man operated transmitter with a radius of approximately 7 miles (11.5 kilometers). About 400 such transmitters are in use in the United States today (in the FM band). Likely it will be possible to economize by placing much larger transmitters in some locations, so this estimate is conservative. My estimates here are further conservative in that each transmitter is only assumed to reach 80% of the students in the schools that it covers and that the average population reached by a transmitter is assumed to be only half what the population density of Java-Madura would indicate. (If the transmission facilities were used for other forms of in-school education or for out of school education, as well as for the primary school uses, then only a fraction of the cost of the transmitter should be charged to elementary school use.) The transmitter is assumed to last 10 years and to have an annual maintenance and operating cost of 10% of its purchase price.

Finally, in order to implement radio, a certain amount of [illegible]r training and orientation will likely be required. This is [illegible]d to cost $10. per teacher ($15. per teacher for training in

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*For approximately $60. it is now possible to purchase a mini-cassette receiver of high quality so that, if desirable, teachers could replay the lessons at times of their own choice. At the other end of the cost range, a pre-set, nontunable receiver would cost much less than $20. Thus the $20. estimate makes allowance for the need for batteries and either maintenance or replacement for defective radios.

two courses), and to be good for ten years since, from an initial point on, the teacher will be learning from the radio.

The above, then, are the basic cost components which will be used in the following analysis. The estimates are believed to be conservative estimates of the state of the art and pessimistic and optimistic variations are also provided. If, however, anyone sharply disagrees with any of the cost assumptions, the following analysis is structured in such a way that he can easily examine the consequences of his own assumptions.

Total, Average, and Marginal Cost Curves. In the following, four different specific alternatives for using radio for substantial supplementation plus teacher training will be analyzed. The first two, Radio 2 and Radio 3 add radio -- for one subject matter and two subject matters, respectively -- with no increase in student to teacher ratio to compensate for the cost. Radio 4 and Radio 5 are alternatives that increase the student to teacher ratio by putting students in grades 3 through 6 on 4 hour shifts without increasing class size. (Most students in grades 1 and 2 are already on shifts.) This also allows for improved classroom utilization. Radio 4 parallels Radio 2 in providing substantial supplementation in a single subject matter; Radio 5 has it for two.* See Table B.3.

All cost equations in this section will be stated in annualized terms. This means that all capital costs, such as programming, must be translated into annual equivalents by the factor $a(r,n) = [r(1+r)^n]/[(1+r)^n-1]$ times the capital cost. Here r reflects the cost of capital and a figure of .15 is used throughout to reflect the high social cost of capital in Indonesia today. n is the expected useful lifetime of the capital outlay; the values of n appeared in the text describing each cost component.

Three cost concepts are used, and these are further described in Section III.A. $T(N)$ is the total annual cost for a way of using

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*Presumably Bahasa Indonesian and arithmetic.

radio if N students use the system. T(N) increases as N increases. A(N) is the average annual cost, or unit cost and is defined to equal T(N)/N . Due to the fixed programming costs, A(N) declines to an asymptotic value as N increases.* The third cost concept is that of marginal or incremental annual cost, M(N) ; this is the annual cost per student of adding new students to a system already in operation. M(N) is equal to the derivative of T(N) with respect too N and simply assumes a constant value in the present cost model. In the next paragraph total cost curves for Radio 2 through Radio 5 are presented; average and marginal cost curves follow from them. In al cases 150 pages of printed material per student per year are assumed to be required for each course (i.e., 150 pages per year are required for Radio 2 and Radio 4, 300 pages per year are required for Radio 3 and Radio 5.

The total cost of Radio 2 will be designated $T_2(N)$, for Radio 3, $T_3(N)$, etc. These equations are expressed in terms of the following variables, whose values were justified in the text.

T = transmitter cost = U.S. $5000.

R = receiver cost = U.S. $20.

B = book cost = U.S. $.0025 per page.

P = programming cost = U.S. $75,000 per course year.

W = teacher workshop cost = $10. for Radio 2 and 4, but $15. for Radio 3 and 5.

The total cost curves follow:

$$T_2(N) = a(.15,12)6P + a(.15,5)150NB + a(.15,5)NR/70 + [.1+a(.15,10)]\ NT/9375 + a(.15,10)NW/35 . \qquad (B.1)$$

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*The UNESCO Report upon which the Appendix is based was prepared prior to the development of the unit cost representations described in Section III. While not incorrect, the presentation of costs in the annualized terms used in this Appendix is, I now feel, less illuminating to a decision-maker than the other would be.

$$T_3(N) = a(.15,12)12P + a(.15,5)300NB + a(.15,5)NR + [.1+a(.15,10)]NT/9375 + a(.15,10)NW/35 . \quad (B.2)$$

$$T_4(N) = a(.15,12)6P + a(.15,5)150NB + a(.15,5)NR/105 + [.1+a(.15,10)]\ NT/9375 + a(.15,10)NW/52.5 . \quad (B.3)$$

$$T_5(N) = a(.15,12)12P + a(.15,5)300\ NB + a(.15,5)NR/52.5 + [.1+a(.15,10)]\ NT/9375 + a(.15,10)NW/52.5 . \quad (B.4)$$

A few notes are in order concerning the construction of these formulae. The source of programming and book costs is fairly clear. For Radio 2, two classes share a receiver; for Radio 3, one class; for Radio 4, three classes (possible because of shifting); for Radio 5, one and a half classes. The .1 appearing in the transmitter cost term is to allow for operations and maintenance. The transmitter term is the same for all uses, though transmitter utilization would vary from 3 hours per day with Radio 2 to 6 or more hours per day for Radio 5, the exact number depending on how the shifting is done. Radio 2 thus leaves more free air time for out of school education, entertainment, or other formal educational uses. (It is in keeping with this report's policy of conservative cost estimation that the full transmitter cost is charged to the primary school use.)

Table B.4 shows expected, pessimistic, and optimistic total cost equations for the each radio alternative. Expected costs are computed from the values of T, R, B, P, and W shown above; pessimistic costs equal 1.5 times expected costs; optimistic costs equal .65 times expected costs. The unit cost equations and values of the marginal costs are shown in tables B.5 and B.6.

The costs shown in Tables B.4 to B.6 are all effective annual costs in which capital costs are spread over their useful lifetime with an assumed social cost of capital of 15%. While the annualized costs give a more accurate representation of the "true" annual costs, it is also valuable to show actual expenditures required, by category and by year. The information in equations B.1 to B.4, and in the cost

Table B.4: Total Annual Cost Formulas[a,b]

	Programming	Printed Material	Receiver	Transmitter	Teacher Training
Radio 2					
Expected	28,225,530 +	38.035N +	28.979N +	54.264N +	19.356N
Pessimistic	42,338,300 +	57.053N +	43.469N +	81.397N +	29.034N
Optimistic	18,346,590 +	24.723N +	18.837N +	35.272N +	12.581N
Radio 3					
Expected	56,451,130 +	76.071N +	57.959N +	54.264N +	29.034N
Pessimistic	84,676,700 +	114.106N +	86.938N +	81.397N +	43.551N
Optimistic	36,693,230 +	49.446N +	37.673N +	35.272N +	18.872N
Radio 4					
Expected	28,225,530 +	38.035N +	19.320N +	54.264N +	12.904N
Pessimistic	42,338,300 +	57.053N +	28.979N +	81.397N +	19.356N
Optimistic	18,346,590 +	24.723N +	12.558N +	35.272N +	8.388N
Radio 5					
Expected	56,451,150 +	76.071N +	38.639N +	54.264N +	19.356N
Pessimistic	84,676,720 +	114.106N +	57.959N +	81.397N +	29.034N
Optimistic	36,693,230 +	49.446N +	25.115N +	35.272N +	12.581N

[a]Costs are in current rupiahs, converted from dollars at Rp. 340 per US dollar.

[b]For any value of N, the number of students in all grades using the system, the sum across the row shows the total annual cost of providing radio for all the students. Capital costs are converted to annual costs on the basis of their expected lifetime and a social cost of capital of 15%.

Table B.5: Average Annual Cost Formulas[a]

Radio 2			
Expected	28,225,530/N	+	140.634
Pessimistic	42,338,300/N	+	210.953
Optimistic	27,519,880/N	+	91.413
Radio 3			
Expected	56,451,130/N	+	217.328
Pessimistic	84,676,700/N	+	325.992
Optimistic	55,039,840/N	+	141.263
Radio 4			
Expected	28,225,530/N	+	124.523
Pessimistic	42,338,300/N	+	186.785
Optimistic	27,519,880/N	+	80.941
Radio 5			
Expected	56,451,150/N	+	188.330
Pessimistic	84,676,720/N	+	282.496
Optimistic	55,039,850/N	+	122.414

[a]Average annual cost is total annual cost, Table 3.1, divided by the number of students, N. These are commonly called unit costs. Costs are in rupiahs.

Table B.6: Annual Marginal Cost[a]

	Radio 2	Radio 3	Radio 4	Radio 5
Expected	140.634	217.328	124.523	188.330
Pessimistic	210.953	325.992	186.785	282.496
Optimistic	91.413	141.263	80.941	122.414

[a]These represent the average annual cost per student of adding a fairly large group of students to the system in a location where there is no transmitter available. For either small or large groups of students, adding to the system in a location with a transmitter would cost about Rp. 54 less than indicated in the table--see column 4 of Table 3.1.

figures preceding these equations is sufficient to determine these costs, if a specific pattern of implementation is assumed. The costs per year of implementing Radio 5 are shown in Table B.7, under the assumption that the decision to implement follows evaluation of the success of two years of program and curriculum development. The rate of implementation is assumed to be one million students per year for ten years; more rapid implementation would, of course, increase costs in early years but decrease them later. Similar time streams of costs can easily be constructed for the other radio alternatives, or for other assumptions about rate of implementation.

Opportunity Cost of Radio. If one wishes to introduce radio into the system without increasing per student instructional costs (i.e., costs of teacher plus radio) by more than a factor of R, one may have to increase the student to teacher ratio in compensation. It is important to know by how much the student to teacher ratio increases, and this can be computed in a straightforward way using the methods of Section III. Let W be a teacher annual wage and S be the student to teacher ratio before introduction of technology. $A(N)$ is, as before, the average annual cost of the technology and we let I be the increase in class size required to make the post-technology per student instructional cost equal R times the pre-technology instructional cost per student of Rp. W/S. The post-technology instructional cost equals $[W + A(N)(S+I)]/(S+I)$; we thus have:

$$W/S = R[W + A(N)\ (S+I)]\ /\ (S+I) \qquad \text{(B.5)}$$

To find the required increase in class size, equation 4.5 is solved for I giving:

$$I = [SW(1-R) + R\ A(N)S^2]\ /\ (W - R\ A(N)S)\ . \qquad \text{(B.6)}$$

Table B.8 shows $(S+I)/S$, the ratio of post- to pre-technology class size for several values of N. It assumes that $S = 35$ and

Table B.7: Cost Per Year For Implementation of Radio 5[a,b]

	Cost Element						
Year	Programming[c]	Transmitter Purchase	Transmitter Operations[d]	Receivers[e]	Printed Material[e]	Teacher Workshop	TOTA
1	225	0	0	0	0	0	22
2	225	0	0	0	0	0	22
3	225	525	53	380	750	285	221
4	225	525	105	380	750	285	227
5	0	525	158	380	750	285	209
6	0	525	210	380	750	285	215
7	0	525	263	380	750	285	220
8	0	525	315	760	1500	285	327
9	0	525	368	760	1500	285	332
10	0	525	420	760	1500	285	338
11	0	525	463	760	1500	285	342
12	0	525	525	760	1500	285	348

[a]Costs are expressed in thousands of US $.

[b]The pattern of implementation whose costs are shown in the table assumes an initial two year period of programming and curriculum development at the end of which time a decision would be made concerning implementation. The implementation rate shown is for one million new students to be receiving radio each year from year three on, for ten years. Thus, for example, in year six there would be four million students using the system. Numbers in the table are based on equation 4.4 and the cost figures shown preceeding the equation 4.1.

[c]The programming and curriculum development costs are based on Radio 5's requirement of 12 year long courses at $75,000 per course, with development spread over four years.

[d]Transmitter operations and maintenance were assumed to cost annually 10% of the assumed purchase price of the transmitter. The total amount spent for this steadily increases through year 12 as more transmitters are installed. Again, it should be stressed that both the transmitter purchase and operations costs in this table are almost surely overestimates; a detailed transmission would improve on the pattern of transmitter use implied in this report.

[e]Annual expenditures on receivers and printed material double in year 8 since, due to the assumed five year lifetime of these item, those installed in year three must be replaced in addition to the new installations.

that W = Rp. 57,300 . When R equals one the per student instructional cost after technology is, of course, the same as it was before. It is interesting to note that if N is even moderately large, the opportunity cost of Radio 5 is only an increase of about five in the student to teacher ratio -- from 35 to about 40. This increase is more than covered in Radio 5 by the shortened school day, without requiring larger class sizes. Table B.8 also gives an idea of the effect of scale of operation on costs. Table B.5 shows how scale affects unit costs in rupiahs while Table B.8 shows the effect in terms of required changes in the student to teacher ratio. For Radio 5, usage by 500,000 to 1,000,000 students per year makes fixed cost per student only a fraction of variable costs.

Probable Performance of Radio. From the surveys mentioned in Section IV, I feel it reasonable to conclude from the literature that radio can teach about as well as a well trained classroom teacher if radio is properly programmed. In computing the effect of using radio, this capability is assumed to reflect itself in reduced dropout and repetition rates.* In my report to UNESCO the impact of radio on graduation and participation levels was computed under the assumption (conservative, I felt) that only one-third of the effect reported in El Salvador would obtain in Indonesia.

To compute the effect of introducing radio, the level of effective expenditures was assumed to increase at a rate of 3% per year and the marginal cost of the radio alternative was added to the present per student cost of 2070.** The fixed costs of program preparation were

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*When TV was introduced in El Salvador, E. McAnamy, J. Mayo and R. Hornik [1970] report that 7th grade dropout rates went from .133 to .09; the reduction in repetition rate was correspondingly greater. More recent information on this may be found in Hornik, et. al. [1972, Ch. 4].

**In the case of Radio 4 and Radio 5, the cost of providing radio must be added to a lower base cost of classroom instruction due to the shortened school day and increased classroom usage. The average value of S is assumed to rise to 42.5 with either of these, and classroom usage is assumed to rise to two classes per classroom.

Table B.8: Increase in Student to Teacher Ratio Required to Finance Radio[a]

Students in System[b]	Radio 2		Radio 3		Radio 4		Radio 5	
	R		R		R		R	
	1.0	1.15	1.0	1.15	1.0	1.15	1.0	1.15
.25	1.182	1.033	1.370	1.233	1.169	1.019	1.338	1.198
.50	1.137	.986	1.252	1.106	1.124	.973	1.225	1.077
1.0	1.115	.964	1.200	1.052	1.103	.952	1.175	1.026
2.0	1.104	.954	1.176	1.027	1.092	.942	1.152	1.002
5.0	1.098	.947	1.162	1.012	1.086	.935	1.139	.988
10.0	1.095	.945	1.157	1.007	1.084	.933	1.134	.984

[a]Entries in the table show the ratio of the student to teacher ratio after technology is introduced to what it is now (assumed to be 35), if the total instructional (teacher + medium) cost is not to increase by more than a factor of R. Clearly this entry must be greater than 1 if R = 1, but it may be less than 1 (decrease in student to teacher ratio) when R = 1.15.

[b]This refers to the number of millions of students in the primary school system who are using radio.

substracted from the available budget, and the methods of Section V were used to compute the number of graduates per year and real participation rates. Under these assumptions all the radio alternatives perform better in terms of graduates and real participation rates than does the present system. Radio 5 does the best, about 25% better than the conventional in terms of graduates and 20% better in terms of participation rate.* These differences are sufficiently large, and were computed under sufficiently conservative assumptions to conclude that the case for use of radio in Indonesia's elementary schools appear quite strong. Before commitment to [illegible]tional use of radio, however, extensive tests of its effecti[illegible] Ind[illegible] should be carried out. These issues are [illegible] us[illegible]amison [1971].

D. Conclusion

In this Appendix I have provided an extended example to both illustrate the methodology developed in the text and, hopefully, to show that that methodology has practical value for educational planners It cannot be stressed too strongly, however, that both the methodology and its applications need further development and testing.

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*For example, under the assumption of a 3% rate of growth of effective expenditures, the projected 1982 real participation rate using radio 5 is 73.6%; the projected 1982 number of graduates is 2.01 million. This contrasts with numbers of 61.4% and 1.59 million for the present system.

REFERENCES

Ahamed, B., M. Blaug, et. al. The Practice of Manpower Forecasting: A Collection of Case Studies. To be published by Penguin Press in 1972.

Anderson, B. and E. Greenberg; with an Appendix by R. McClung. Educational Production Functions for Teacher-Technology Mixes. St. Louis, Missouri: Washington University Program on Applications of Communications Satellites to Educational Development, Memorandum 72/2, March 1972.

Averch, H., S. Carroll, T. Donaldson, H. Kiesling, and J. Pincus. How Effective is Schooling? A Critical Review and Synthesis of Research Findings. Santa Monica, California: The Rand Corporation, R-956-PCSF/RC, March 1972.

Beeby, C. E. Qualitative Aspects of Educational Planning. Paris: UNESCO International Institute for Educational Planning, 1969.

Beeby, C. E. The Quality of Education in Developing Countries. Cambridge, Massachusetts: Harvard University Press, 1966.

Bennet, N. Primary education in rural communities: an investment in ignorance? UNESCO International Institute for Educational Planning, Paris. Unpublished report, 1971.

Blaug, M. The rate of return on investment in education. In M. Blaug (Ed.), Economics of Education 1. Baltimore, Maryland: Penguin Books, 1968.

Blaug, M. Economics of Education: A Selected Annotated Bibliography, 2nd Ed. Oxford, England: Pergamon Press, 1970.

Bourret, P. I. Television in rural areas--a low cost alternative. A Paper Submitted to the Seminario Interamericano de Educacion y Comunicacion Social, 1971.

Bowles, S. Planning Educational Systems for Economic Growth. Cambridge, Massachusetts: Harvard University Press, 1969.

Carnoy, M. The political economy of education. To appear in M. Carnoy (Ed.), The Political Economy of Education.

Chu, G. and Schramm, W. Learning from Television: What the Research Says. Washington, D. C.: National Association of Educational Broadcasters, 1968.

Coleman, J. E., et. al. Equality of Educational Opportunity. Washington, D. C.: U.S. Government Printing Office, 1966.

Coombs, P. H. What is Educational Planning? Paris: UNESCO International Institute for Educational Planning, 1970.

Coombs, P. and J. Hallak. An Introduction to Educational Cost Analysis. To be puslished.

Daroesman, R. Finance of education: part I. Bull. of Indon. Econ. Stud., VII, 1971, 61-95.

Daroesman, R. Finance of education: part II. Bull. of Indon. Econ. Stud., VIII, to appear March 1972.

Denison, E. F. Why Growth Rates Differ. Washington, D. C.: The Brookings Institution, 1967.

Denison, E. F. The Sources of Economic Growth in the United States and the Alternatives Before Us. Supplementary Paper No. 13, Committee for Economic Development, New York, 1962.

Emerson, L. H. Indonesia--Educational Planning (Serial No. 960/BMS.RD/EP). Paris: UNESCO, January, 1969.

Forsythe, R. Instructional radio: a position paper. Stanford, California: ERIC Clearinghouse, 1970.

Griffiths, V. L. The Problems of Rural Education. Paris: UNESCO International Institute for Educational Planning, 1968.

Griliches, Z. Notes on the role of education in production functions and growth accounting. In W. L. Hansen (Ed.) Education, Income, and Human Capital. New York: Columbia University Press, 1970.

Griliches, Z. and Jorgensen, D. W. The explanation of productivity change. Review of Economic Studies, XXXIV (3), No. 99, 1967.

Guthrie, J. W. A survey of school effectiveness studies. In A. Mood (Ed.) Do Teachers Make A Difference? Washington, D. C.: U.S. Government Printing Office, 1970.

Hall, G., and M. Rapp. Case Studies in Educational Performance Contracting: Gary, Indiana. Santa Monica: The Rand Corporation; R-900/4, December 1971. See particularly pp. 59-60.

Hansen, W. L. Rates of return to investment in schooling in the United States. In M. Blaug (Ed.) Economics of Education 1. Baltimore, Maryland: Penguin Books, 1968.

Hornik, R., H. Ingle, J. K. Mayo, J. A. Mayo, E. McAnany, and W. Schramm. Television and Educational Reform in El Salvador: Report on the Third Year of Research. Research Rept. 10, Institute for Communication Research, Stanford University, March 1972.

Jamison, D. Studies in Individual Choice Behavior. Ph.D. Thesis, Dept. of Economics, Harvard University, January 1970. Santa Monica, California: The Rand Corporation, P-4255, 1970.

Jamison, D. Alternative strategies for primary education in Indonesia a cost-effectiveness analysis. Stanford, California: Graduate School of Business Research Paper 46, 1971.

Jamison, D. and Ball, J. Communication economics of computer-assisted instruction for rural areas: Satellite vs. commercial phone systems. Paper presented at the XXIInd International Astronautical Congress of the International Astronautical Federation, Brussels, September 1971.

Jamison, D., Fletcher, J. D., Suppes, P. and Atkinson, R. Cost and Performance of Computer-Assisted Instruction for Education of Disadvantaged Children. To appear in J. Froomkin and R. Radner (Eds.) Education as an Industry National Bureau of Economic Research and Columbia University Press.

Jamison, M. Low Cost Educational Systems for Developing Countries: An Application of Systems Analysis to Educational Planning. Unpublished Ph.D. thesis, School of Education, University of California at Los Angeles, 1967.

Katzman, M. The Political Economy of Urban Schools. Cambridge, Massachusetts: Harvard University Press, 1971.

Kemeny, J. G., Schleifer, A., Snell, J. L. and Thompson, G. L. Finite Mathematics with Business Applications. Englewood Cliffs, New Jersey: Prentice-Hall, Inc., 1962.

Leslie, J. Instructional radio for developing countries. Unpublished paper, Stanford University, 1971.

McAnany, E., J. Mayo, and R. Hornik. Television and Educational Reform in El Salvador. Research Rept. 4, Institute for Communication Research, Stanford University, July 1970.

Parnes, H. S. Manpower analysis in educational planning. In H. S. Parnes (Ed.), Planning Education for Economic and Social Development. Paris: O.E.C.D., 1964. Reprinted in M. Blaug (Ed.), Economics of Education 1. Middlesex, England: Penguin Press, 1968.

Psacharoupoulos, G. Returns to Education: An International Comparison. To be puslished by Elsevier Publishing Company.

Schramm, W., Coombs, P. H., Kahnert, F. and Lyle, J. The New Media: Memo to Educational Planners. Paris: UNESCO International Institute for Educational Planning, 1967.

Schramm, W., Coombs, P. H., Kahnert, F. and Lyle, J. New Educational Media in Action: Case Studies for Planners (Volumes I, II and III). Paris: UNESCO International Institute for Educational Planning, 1967.

Schultz, T. W. Transforming Traditional Agriculture. New Haven, Connecticut: Yale University Press, 1964.

Schultz, T. W. Investment in Human Capital. New York: The Free Press, 1971. See Chapter 7 in particular.

Sen, A. Choice of Techniques: An Aspect of the Theory of Planned Economic Development, 3rd Ed. Oxford, England: Basil Blackwell, 1972.

Slors, P. A. Some bottlenecks in Indonesia's educational structure, with a view on its future. Badan Pengembangan Pendidikan, Djakarta, unpublished report, January 12, 1971.

Smith, D. A survey of recent experimental and survey evidence on the effects of class size on the achievement of primary and secondary students. Paper prepared for Federal Council on Science and Technology Panel on Productivity in Education, 1972.

Smith, D. Some notes on early teaching by radio in the U.S. Paper prepared for Federal Council on Science and Technology Panel on Productivity in Education, 1972.

Vaizey, J. The Economics of Education. London: 1962.

Wells, S. A survey of input-output studies in education. Paper prepared for National Institute of Education Planning Unit, 1972.

Woodhall, M. Cost-Benefit Analysis in Educational Planning. Paris: UNESCO International Institute for Educational Planning, 1969.

APPENDIX V

Determining the Least-Cost National System for Distributing Educational Television with Audio Feedback

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(A study supported by a subcontract to the Academy for Educational Development under AID Contract 2829, January, 1973.)

INTRODUCTION

I. A simple relationship exists between a nation's gross national product (GNP) and its telephone denisity (the number of telephones per 1000 population).

1. It should not be inferred from this that the demand for telephone service can be characterized by the same simple relationship to GNP. Only in the more developed countries is the investment in telephone plant sufficient to produce a demand-limited market. The budget constraints of less developed countries produce a definitely supply-limited situation, there is more demand than there is facility to satisfy the demand.

2. Especially in such a supply-limited situation, there is impetus to determine the least-cost method of providing service, since the target for the communications entities of these less developed countries is a development plan to upgrade the present telecommunications system to make it compatible with the socioeconomic level of the country, and to do so within the telecommunications budget.

It appears that the telecommunications satellite can significantly reduce the costs of service to dispersed populations or subscribers (e.g., interconnection of cable television companies) while maintaining the same standard of performance as obtained with terrestrial systems. In fact, we believe that the satellite can make some services economically feasible that otherwise could not be supported by less developed countries, and that further experience with telecommunications via satellite will improve its economic advantage for these services.

An indication of the continuing trend to lower costs for satellite services is the dramatic reduction in space-segment per-year costs of a telephone circuit. Using figures generally available, the graph in Fig. A-V-1 was plotted.

3. It should be emphasized that these costs do not include the ground segment of the system. The cost per circuit year decreased by well more than an order of magnitude over the 5-1/2-year period between 1965 and 1971.

This advantage, however, may not be realizable unless the large cost of the satellite, and, to a much lesser extent, the costs of the earth stations, are shared in a multipurpose venture. Such a venture is, of course, entirely possible from a technical standpoint, since a satellite can simultaneously receive and retransmit several dissimilar signals (be they telephone, telegraph, television, analog or digital). We, therefore, strongly recommend that coordinated inter-agency planning be encouraged where a national satellite is being considered.

A prime candidate for a share in a multipurpose system, in addition to commercial telephony and television, is educational programming. It has received wide-spread attention over the past few years, especially in applications for less developed countries. In part, this is because of its potential for reducing costs. Traditional approaches to education have always been labor intensive. Largely for this reason the present cost squeeze in education has become accute. Other fields of activity have benefitted from technological innovations and improvements

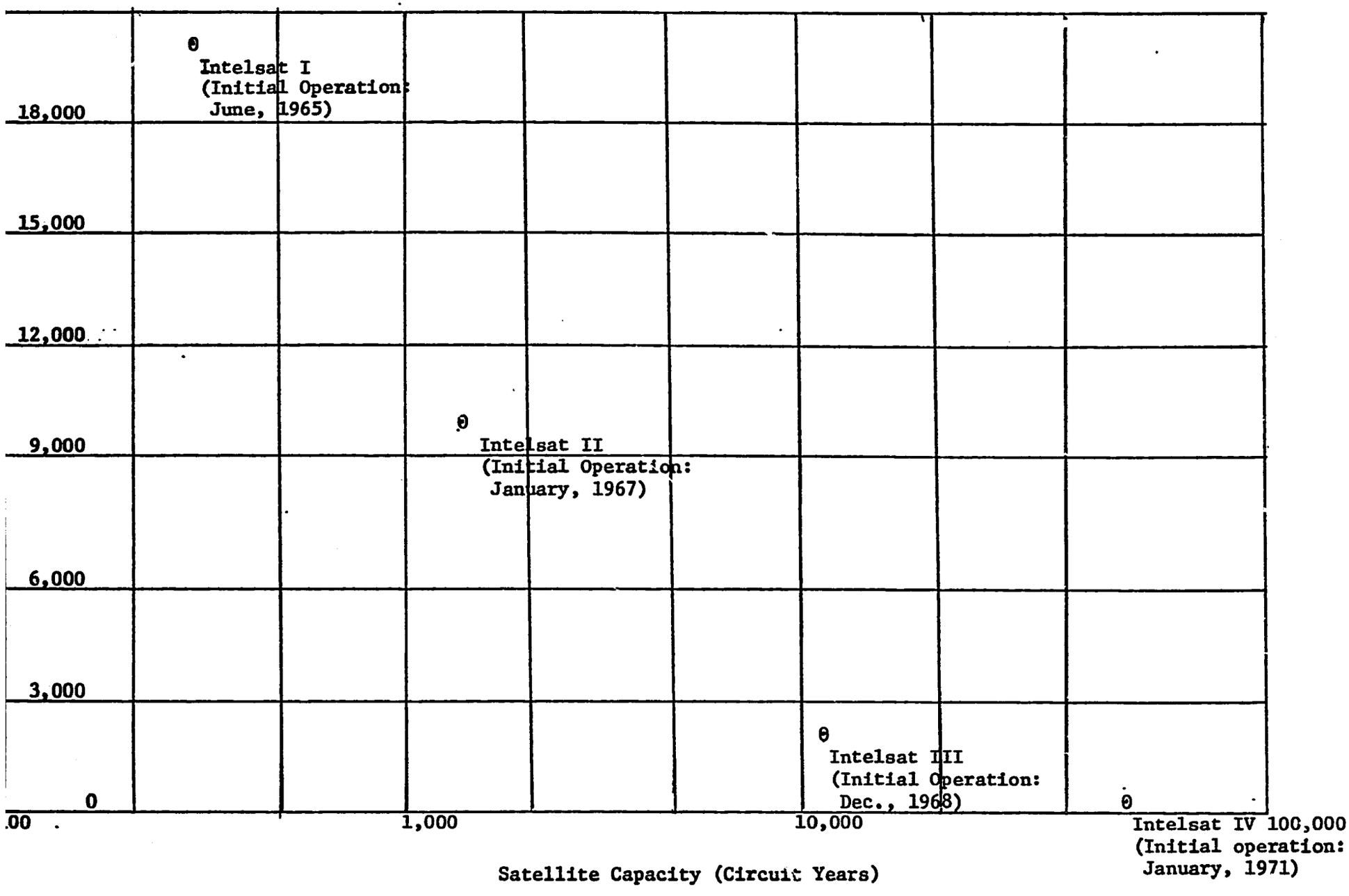


Figure A- V-1. Intelsat IV Satellite Costs. The in-orbit per-circuit per-year cost versus the satellite capacity (in circuit-years, over the design lifetime of the satellite.)

to increase the productivity of their employees. This rise in efficiency permitted higher wages. Although no corresponding increase in efficiency occurred in education, teachers and administrators participated in the upward wage trends. As Baumol states, "...(this) suggests that, as productivity in the remainder of the economy continues to increase, costs of running the educational organizations will mount correspondingly, so that whatever the magnitude of the funds they need today we can be reasonably certain that they will require more tommorrow, and even more on the day after that.

4. Reducing the labor-intensive nature of the educational enterprise can, of course, help to open the way for technologically motivated reductions in cost. With low-cost earth stations, the distribution of educational materials via television, with or without a voice talk-back capability, becomes a very attractive alternative to the slow and costly process of specialized training of teachers and the subsequent continual problem of motivating teachers to work in rural areas. Due care must be exercised so that education of feelings, attitudes, values, and behavior does not suffer as cognative education is being helped with remote programming expertise.

This report will present results of our work and give several examples of the capability of programs developed by us to determine the least-cost system suitable for educational television program distribution with audio feedback. It will also outline the work in progress toward the development of a model to determine a least-cost configuration of a multipurpose system to provide information distribution.

II. Least-Cost TV/Return Audio System

A. Terrestrial systems.

An investigation of terrestrial technologies revealed that only coaxial cable and microwave radio facilities have sufficient bandwidth to carry television programming. Except for relatively short distances, microwave radio is the less expensive of the two. A typical radio link consists of the transmit terminal, several repeaters and the destination terminal. These are shown schematically in Figure A-V-2. The average distance between repeaters (called the hop distance) is 30 miles.

Each origin and destination terminal requires the following equipment:

Transmitter or receiver (per TV channel)	$ 4,500
Antenna and feed	1,900
Standby batteries and charges--	
First channel	1,600
Each additional channel	200
Tower (150 feet guyed)	6,000
Installation and alignment--	
First channel	1,000
Each additional channel	500
Voice feedback equipment	
Transmitter or receiver	4,500
Antenna and feed	1,900
Batteries and charger	200
Multiplex equipment--Heavy route per channel (voice)	2,000
Light route, per channel (voice)	1,000
Installation and alignment --	
First Channel (voice)	900
Each additional channel (voice)	200

These costs can be represented in equation form by

$C_{mt}(c) = \$24,500 + \$7,400(c-1)$ for heavy routes (voice)

$C_{mt}(c) = \$23,500 + \$6,400(c-1)$ for light routes (voice)

where $C_{mt}(c)$ is the cost of microwave terminal-station equipment and c is

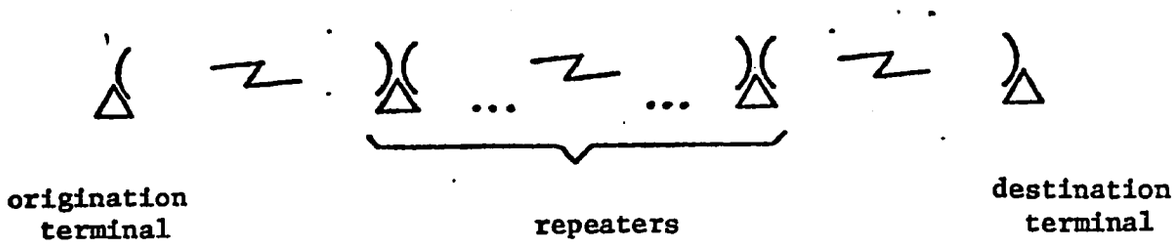


Figure A- V-2. A microwave radio relay link.

Each repeater station requires the following equipment:

Transmitter and receiver (per TV Channel)	$ 7,000
Antennas and feed	3,800
Standby batteries and charger--	
First channel	2,000
Each additional channel	200
Tower (150 feet guyed)	6,000
Installation and alignment--	
First channel	1,300
Each additional channel	500
Voice feedback equipment	
Transmitter and receiver	7,000
Antennas and feed	3,800
Batteries and charger	200
Installation and alignment	1,100

or in equation form,

$$C_{mr}(c) = \$32,200 + \$7,700(c-1)$$

We made an important simplification at this point of our analysis. A microwave terminal station (no retransmission of the video signal is required) would only be used in the distribution network at the ends of branches where a final destination has been reached and the particular city in question is not serving, simultaneously, as a repeater link for other cities. Nevertheless, each terminal station will have its video transmit counterpart somewhere upstream toward the origination station. This is significant because it allows the costs of the microwave system to be modeled (on the low side) as the total number of stations used, whether terminal or repeater, times the cost of a repeater station: or, in equation form,

$$C_{ms}(c,N) = (1 + \eta(N))NC_{mr}(c)$$

where $C_{ms}(c,N)$ is the cost of the microwave system

N is the number of cities being served by the system

c is the number of TV channels being distributed.

$\eta(N)$ is the ratio of the number of microwave repeater stations

To make the cost-components of a repeater station comparable to those included later on for satellite earth stations, the equipment costs of a repeater station were modified to reflect the costs of land (land, grading, roads, and tower foundation) and maintenance. Maintenance was assumed to be 15 percent of first cost (an average figure used by Pacific Telephone and Telegraph Co.) over a 25-year period (PTT uses 15.99 years), and land costs were assumed to be $8,000 (this allows for the fact that not all sites will require land or towers). The other costs incident to the design and implementation of the system (such as transportation, documentation, spare parts, engineering, commercial power, or connection) were broadly assumed to be common to any other telecommunications system being considered and were not, therefore, explicitly included. (Another reason is that one comparison of the cost of a microwave system to the cost of a satellite system was done on the supposition favorable to the microwave system--that no intermediate repeater stations would be required, i.e., $\eta(N)=0$. Thus each station would be located at or near a city to be served, similar to the placement of satellite earth stations if a satellite system were used, and support costs for either type of installation would be fairly comparable.)

The addition of these costs to $C_{mr}(c)$ gives:

$$C_{mr}(c) = \$72,600 + \$17,500(c-1)$$

and

$$C_{ms}(c,N) = (1+\eta(N))N(\$72,600 + \$17,500(c-1))$$

The values of N and c are known in any given situation. $\eta(N)$, on the other hand, can be known accurately only after a preliminary route survey with topographic maps and path profiles has been completed.

It was sufficient for our purposes, however, to derive a rough estimate of the functional dependence of n on N. A uniform distribution of cities throughout the entire area to be served was assumed. Although this is not likely for an actual system, it might be argued that the number of repeaters required to serve such a distribution could be considered as an upper bound since any departure from uniformity would allow advantage to be taken of the clustering that would appear. It was further assumed that the origination station was located at one of the N cities to be servied. The straight forward derivation of n(N) is as follows:

Consider a region of rectangular shape L miles long by W miles wide. For a uniform distribution, each city will be at the center of a smaller rectangle that is $L/N^{1/2}$ miles long by $W/N^{1/2}$ miles wide (see Fig. A- V-3). The intercity separation distance is thus either $L/N^{1/2}$ miles (long link) or $W/N^{1/2}$miles (short link) depending on whether the direction of travel is parallel to the length or to the width of the rectangle. If,insofar as possible, cities are connected to their neighbors using short links, fewer intercity repeaters will be required than with any other link pattern. With this pattern, the network will consist of $(N^{1/2}-1)N^{1/2}$short links and $(N^{1/2}-1)$ long links.

In calculating the total number of intercity repeaters implied by this pattern, we let h represent the average interrepeater (hop) distance and D represnet the distance between cities, or the link length. Because h is the average hop distance and not the maximum, and because of the large numbers of equal length links involved, a reasonable approximation for the average number of repeaters per intercity link as a function of link length is taken to be $n = (D/h-1)$. This number will generally not be an integer.

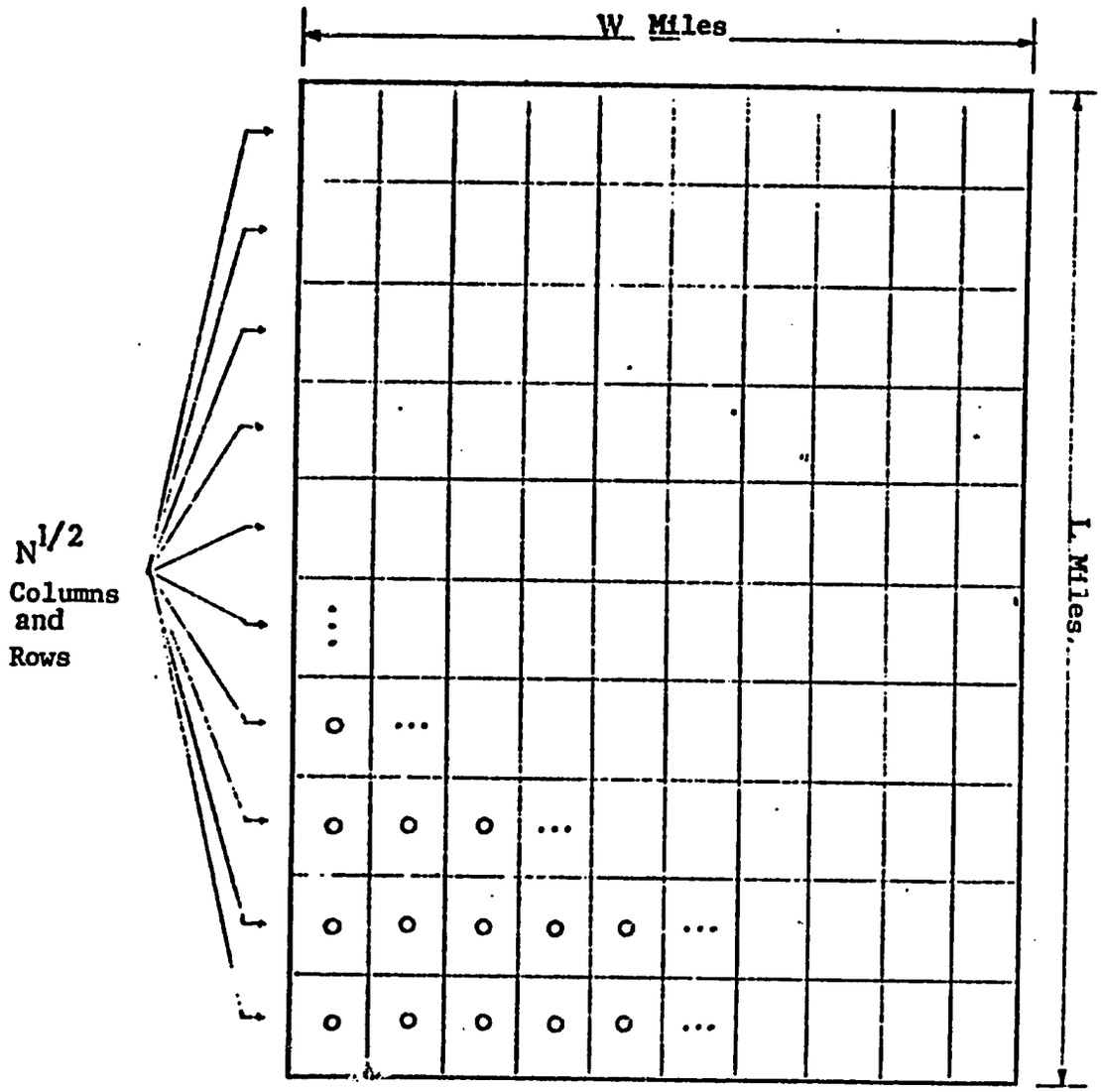


Figure A-V-3.

A rectangular educational satellite region containing N uniformly distributed cities

An equation for the total number of intercity repeaters, Nn, may now be written:

$$N\eta = N^{1/2}(N^{1/2}-1) \times \text{(the average number of repeaters in a short link)}$$

$$+N^{1/2}-1) \times \text{(the average number of repeaters in a long link)}$$

$$\eta = N^{1/2}(N^{1/2}-1)\ (W/hN^{1/2}-1) + (N^{1/2}-1)\ (L/hN\ \ -1)$$

For very large N, this equation would yield a negative value for n. To prevent this, η was defined as the larger of the value given by the above equation and zero. For L = 1,500 miles, W = 1,000 miles (corresponding roughly to the size of the Rocky Mountain region), and h = 30 miles, Table A-V-1 gives some representative values of N and the corresponding η.

B. Satellite System.

A satellite long-distance transmission system consists of the following components: 1) a video-transmit, audio-receive up-link earth station at each television origination point; 2) a satellite; and 3) a video-receive, audio-transmit earth station at each local receive point. (the number of local receive points will generally be greater than the number of cities being served. In any event, it cannot be less.)

Two types of video-receive earth stations may be distinguished according to their received output signal-to-noise ratio. Earth stations that feed local distribution subsystems would need a higher output ratio than would earth stations that serve isolated subscribers (no further distribution is necessary). For simplicity, our analysis assumes that all earth stations provide the same higher quality signal as that required for redistribution. A slight cost savings could be realized in any actual implementation by limiting use of the higher quality station

N	n
100	2.46
250	1.16
500	.52
1,000	.07
1,140	.00
10,000	.00

Table A-V-1.

Representative Values of N and the Corresponding n.

The cost of the satellite distribution system may be expressed as:

$$C_{ss}(c,N) = C_s(c,N) + C_b(c,N) + NC_e(c,N)$$

where

$C_{ss}(c,N)$	is the cost of the satellite system (in dollars)
c	is the number of video channels carried by the satellite
N	is the minimum number of video-receive earth stations in the network
$C_s(c,N)$	is the cost of that part of the space segment of the system actually used by the educational system (here is an implicit assumption of a multipurpose system and the consequent cost saving through sharing) (in dollars).
$C_b(c,N)$	is the cost of the master video-transmit, audio-receive station(s) (in dollars).
$C_e(c,N)$	is the cost of a video-receive, audio-transmit earth station (in dollars)

The earth station costs include the following:

1) Equipment costs

2) Site costs (assumed to be 40 percent of the antenna costs)

3) Installation costs (assumed to be 10 percent of the equipment costs)

4) The present worth of maintenance costs over an assumed 25-year lifetime using a discount rate of 10 percent. Annual maintenance costs are assumed to be 15 percent of equipment costs.

5) The cost of channel separation and demodulation to baseband for each video channel received. On a per-channel basis, this cost has been estimated to be near $1,200, as follows. A lower bound may be established by looking at the function and cost of an ITFS (instructional television fixed service) down converter. The down converter, used with an ITFS receive-station, does no more than shift the frequency of

the incoming rf signal down to the proper TV carrier frequency, using a double conversion process, and then amplifies the result. The cost of the down converter is $800. Demodulation is not included (it, of course, is not necessary in ITFS transmissions.) An upper bound may be taken to be $1,500. This is the cost of the equipment needed at a cable headend site to prepare a TV signal, received from a microwave link, for transmission on the cable. This $1,500 does not include demodulation either, but does include AM modulation, frequency translation to the proper cable channel, and power amplification. Insofar as demodulation can be considered to require equipment of lower cost than does modulation, the comporomise figure of $1,200 is reasonable.

The computer program developed here at Stanford uses extensive cost information that we gathered on earth station components together with a value for the cost per watt per year of satellite radio frequency power to calculate earth station costs and configurations for the criterion of minimum overall satellite system cost. Thus, if the cost per watt-of-space-segment-use increases, minimizing total system cost would require that the earth stations be made more sensitive and consequently more costly, so that less satellite power need be used. Similarly, if only a few earth stations are to be constructed, their unit cost should be much higher than if many are needed.

The range of per-watt-of-space-segment charges that is used in the following printouts is based on matching in-orbit satellite capacity with various assumed demand curves over time for that capacity. The present worths of the costs that would be incurred in providing sufficient satellite capacity to just meet these demands are calculated using the costs of currently proposed satellites. Then the amount that must be charged for a watt-year of satellite capacity is determined such that the present worths of the revenue streams associated with each demand curve are equal to the present worths of the costs, respectively, of satisfying

the demand. The range of charges runs from $C_{w/y}$= \$15,000 per watt-year to $C_{w/y}$= \$50,000 per watt-year. $C_{w/y}$ is the cost to the educational system of one watt of satellite radio frequency power for one year.

The costs shown in Tables A-V-2 through A-V-7 are representative of those obtaining for a country whose area may be covered by a satellite antenna of 10 feet equivalent diameter and for which the slant range to the satellite at the furthest 3-dB beam edge is comparable to any location in Northern Montana.

C. Cost Comparison.

The cost comparison between the satellite terrestrial systems as described above is shown in Figures A-V-4 and A-V-5. It is based on the equations for C_{ms} and C_{ss} developed in the last two sections. Figure A-V-4 gives the costs for systems that carry four video channels and Figure A-V-5 presents the costs for 12-channel systems. Each figure also includes a plot of what the microwave network would cost if n(N) =0. This approximates the case where the cities involved are not apread throughout an entire region but are, in fact, so situated that very few intercity repeaters would be needed.

It may be seen that for any regional network serving even as few as 100 cities the satellite system is dramatically less expensive than the terrestrial system. In fact, providing 12 channels by the satellite is less costly than providing four channels by the microwave network, even though to provide 12 channels by the satellite involves stacking the TV channels so close together in frequency that adjacent channels must be

transmitted on carriers that are cross-polarized with respect to each other (permitting some overlapping occupancy of the available frequency spectrum) and the earth stations must be equipped with two antennas and two preamplifiers.

In view of this cost dependency on the number of cities involved, we may ask how many cities may require service in a typical regional system. An example of a region that might actually be served by such an education system is the Rocky Mountain region. In the eight states of this region there are 1168 cities. There are 361 cities of greater than 2,000 population and 100 cities of greater than 10,000 population. An educational system transmitting to this area would be of most use in the smaller cities where large or specialized curricular aids are not readily available. Thus, most of the 361 cities of greater than 2,000 population would probably wish service. This is an obvious case, then in which the satellite system would be less expensive.

Satellite System Cost Parameters with $C_{w/y}$=$15,000 and c=4

N	$C_c(c, N)$	$C_b(c, N)$	$C_s(c, N)$	$C_{lds}(c, N)$
100	13, 277	190, 453	1, 719, 027	3, 237, 180
250	11, 404	244, 954	1, 969, 774	5, 065, 735
500	9, 437	263, 594	2, 626, 464	7, 608, 640
1, 000	8, 115	295, 771	3, 515, 082	11, 925, 763
2, 500	6, 999	427, 823	5, 101, 800	23, 027, 488
5, 000	6, 459	520, 435	6, 886, 546	39, 700, 528
10, 000	6, 085	697, 998	9, 391, 256	70, 938, 144

Table A-V-2

Satellite System Cost Parameters with $C_{w/y}$=$30,000 and c=4

N	$C_c(c, N)$	$C_b(c, N)$	$C_s(c, N)$	$C_{lds}(c, N)$
100	21, 118	244, 623	2, 025, 320	4, 318, 709
250	12, 392	264, 884	3, 407, 118	6, 770, 074
500	11, 101	293, 152	3, 828, 800	9, 672, 456
1, 000	9, 218	400, 766	5, 044, 458	14, 663, 023
2, 500	7, 638	492, 540	7, 430, 076	27, 016, 832
5, 000	6, 881	623, 697	10, 014, 704	45, 045, 536
10, 000	6, 365	860, 615	13, 600, 203	78, 108, 272

Table A-V-3

Satellite System Cost Parameters with $C_{w/y}$=$50,000 and c=4

N	$C_c(c, N)$	$C_b(c, N)$	$C_s(c, N)$	$C_{lds}(c, N)$
100	34, 185	258, 583	1, 890, 907	5, 568, 063
250	19, 415	287, 412	3, 418, 220	8, 559, 295
500	11, 785	389, 192	5, 663, 671	11, 945, 315
1, 000	10, 338	439, 389	6, 659, 990	17, 437, 072
2, 500	8, 287	564, 274	9, 812, 110	31, 093, 520
5, 000	7, 311	739, 032	13, 221, 370	50, 516, 352
10, 000	6, 649	1, 045, 246	17, 928, 640	85, 466, 640

Table A-V-4

Satellite System Cost Parameters with $C_{w/y}$=$15,000 and c=12

N	$C_c(c, N)$	$C_b(c, N)$	$C_s(c, N)$	$C_{lds}(c, N)$
100	44, [illegible]	328, 036	3, 0[illegible], 475	7, 832, 028
250	28, 173	354,861	5, 168, 194	12, 566, 348
500	24, 865	457, 012	6, 227, 536	19, 117, 216
1, 000	21, 722	506, 487	8, 287, 900	30, 516, 720
2, 500	19, 078	739, 824	12, 098, 080	60, 527, 104
5, 000	17, 832	919, 098	16, 257, 658	106, 335, 184
10, 000	16, 980	1, 248, 249	22, 008, 800	193, 059, 920

Table A-V-5

Satellite System Cost Parameters with $C_{w/y}$=$30,000 and c=12

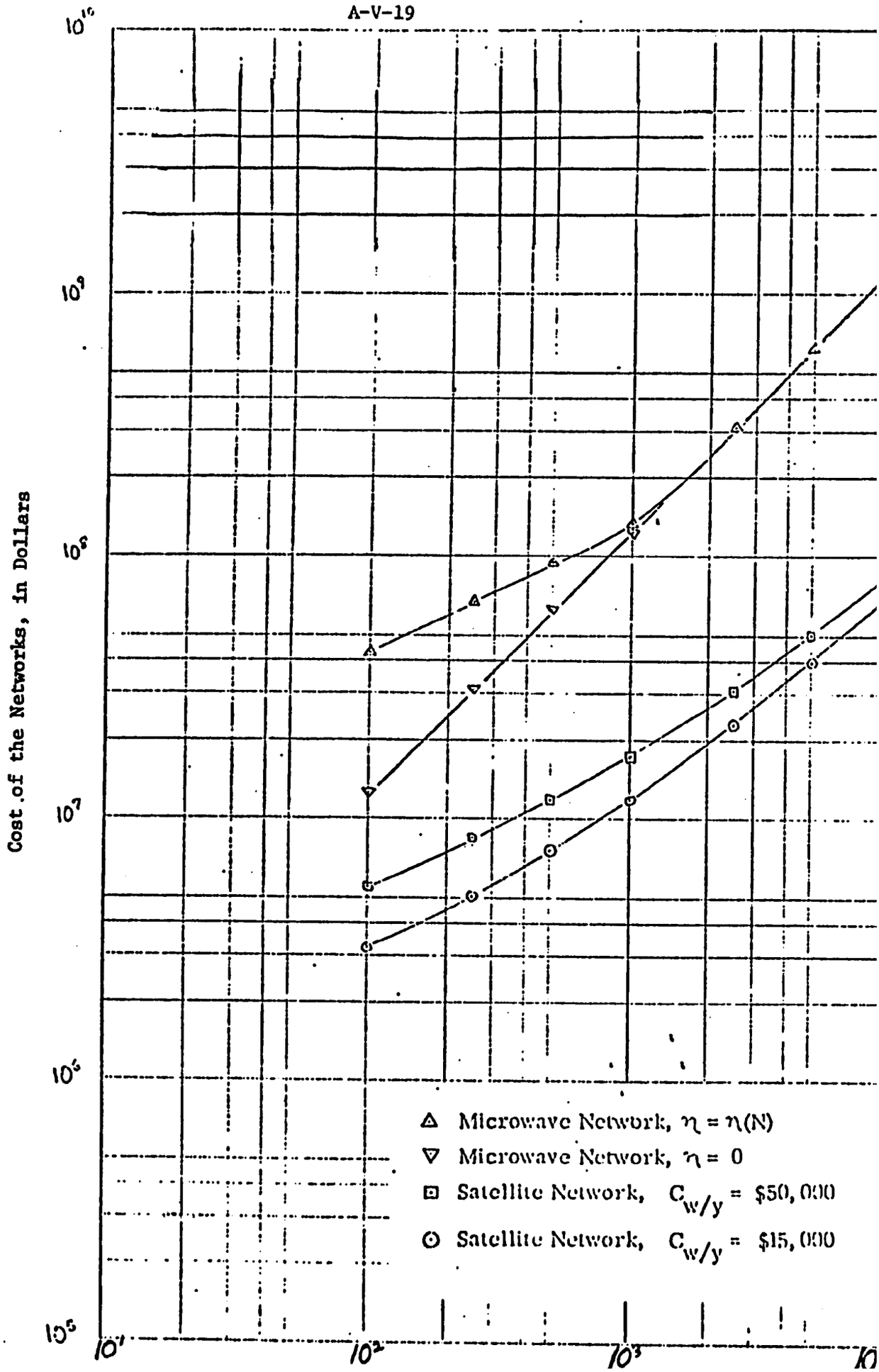
N	$C_c(c, N)$	$C_b(c, N)$	$C_s(c, N)$	$C_{lds}(c, N)$
100	68, 250	354, 861	3, 418, 916	10, 598, 739
250	41, 094	460, 870	6, 113, 468	16, 847, 920
500	27, 071	614, 462	10, 116, 378	24, 266, 496
1, 000	24, 318	689, 948	11, 992, 616	37, 000, 112
2, 500	20, 606	877, 653	17, 622, 336	70, 051, 760
5, 000	18, 844	1, 140, 515	23, 679, 872	119, 038, 928
10, 000	17, 650	1, 601, 609	31, 992, 640	210, 097, 520

Table A-V-6

Satellite System Cost Parameters with $C_{w/y}$=$50,000 and c=12

N	$C_c(c, N)$	$C_b(c, N)$	$C_s(c, N)$	$C_{lds}(c, N)$
100	81, 443	450, 293	5, 082, 237	13, 676, 797
250	41, 094	606, 186	9, 968, 821	20, 848, 576
500	38, 959	669, 417	10, 121, 574	30, 270, 368
1, 000	26, 058	773, 462	17, 017, 984	43, 849, 040
2, 500	22, 161	1, 030, 177	23, 275, 408	79, 706, 912
5, 000	19, 873	1, 386, 146	31, 278, 336	132, 027, 904
10, 000	18, 332	1, 997, 533	42, 237, 200	227, 550, 608

Table A-V-7


Cost of the Networks, in Dollars
10^{10}
10^{9}
10^{8}
10^{7}
10^{6}
10^{5}
10^{1}
10^{2}
10^{3}
Microwave Network, $\eta = \eta(N)$
Microwave Network, $\eta = 0$
Satellite Network, $C_{w/y}$ = \$50,000
Satellite Network, $C_{w/y}$ = \$15,000

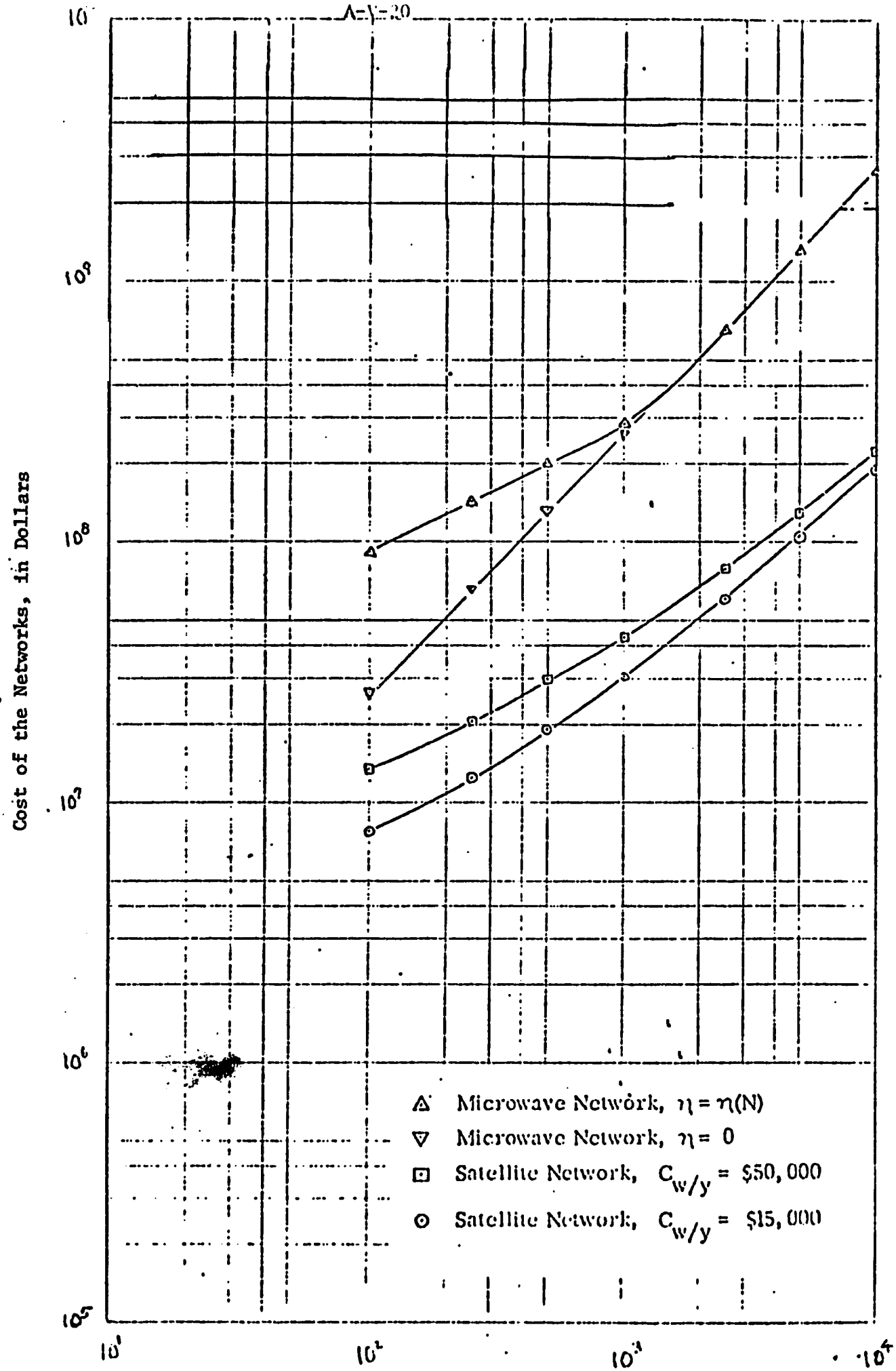


Figure A-V-5. Terrestrial Microwave and Satellite Systems Costs versus N, the Number of Cities in the Networks (c=12).

III. Examples of Program Capability

Employing our present computer program we have made representative calculations of the costs of satellite service for four Latin American countries. The program accepts as input parameters the values of the variables shown on page A-V-9 above, as well as the following variables:

1. The longitude of the country's geographical center
2. The latitude of the country's northernmost boundary
3. The latitude of the country's southernmost boundary
4. The longitude of the westernmost boundary
5. The longitude of the easternmost boundary
6. The latitude for the maximum slant range calculation
7. The longitude for the maximum slant range calculation

Two cases were considered for each of four less developed countries (Brazil, Peru, Mexico, and Colombia). First, it was assumed that only one TV origination station would be provided and that it would be at the capital of the country. It would transmit to receive stations located at every city of 2,000 or more inhabitants. Second, it was assumed that there would be a TV origination station at all state capitals and at any large population center (these places are shown on the accompanying maps). With only one TV origination station, the number of channels carried for educational purposes was specified as 4. When more than one TV origination station is permitted, each is assumed to be capable of transmitting two channels to every village (any size) with the satellite carrying a maximum of 12 channels at any one time. The number of villages was determined by looking at either the latest census of population for the given country if available in the Government Documents Section of the Stanford Library, or in the 1966 edition of the Hammond World Atlas if no census was available.

Brazil

Case 1. Brazil's 1960 census of population lists 1,797 cities, towns, above 2,000 population. We used 1,800.

Case 2. Brazil's 1960 census of population lists 6,535 cities, towns, and villages (total). There are 28 cities on the accompanying map that were used as origination stations, and that number of receive stations will be rounded to 6,500. (By way of contrast, the Hammond World Atlas lists only some 746 cities, towns, and villages with only three of these having populations lower than 1,000)

Peru

Case 2. Peru's Anuario Estadistico Del Peru, 1966 shows 24,908 places of greater than 50 inhabitants. However, only 7,969 of these have more than 200 inhabitants. We used the figure of 7,950 in the program. (Hammond lists only 363 for the total number of towns and villages and cities). The number of origination stations is equal to 12.

Case 1. Peru's Anuario Estadistico Del Peru, 1966 lists 355 cities and towns larger than 2,000 population. (Hammond lists only 148).

Mexico

Case 1. The Anuario Estadistico de los Estados Unidos Mexicanos, 1966-1967 has nine categories of localities; ciudades, villas, pueblos, congregaciones, haciendas, fincas, ejidos, ranchos, rancherias, and otras. In running this program the arbitrary choice was made to assume that the first three categories include all cities and towns larger than 2,000 population. This number is (362 + 528 + 5,189) = 6,079. We used 6,050.

Case 2. To the above number was added the number of congregaciones to bring the total to about 11,000. There are 22 cities at which origination stations are situated.

Colombia

Case 1. There are 193 cities and towns listed in Hammond as larger than 2,000 population.

Case 2. Hammond shows 306 as the total number of cities, towns, and villages. There are 18 sites for origination stations.

BRAZIL
Area: 3,286,170 sq. mi.
Population: 83,900,000 (1966)
Rural 59.7 per cent (1960)
46.0 per cent (1980 projecte
BOA VISTA
MACAPA
BELEM
SAO LUIS
MANAUS
FORTALEZA
TERESINA
NATAL
JOAO PESSOA
RECIFE
MACEIO
ARACAJU
SALVADOR
CUIABA
BRASILIA
GOIANIA
BELO HORIZONTE
VITORIA
CAMPINAS
SAO PAULO
NITEROI
RIO DE JANEIRO
SANTOS
CURITIBA
FLORIANOPOLIS
PORTE ALEGRE
RIO BRANCO
PORTO VELHO

*** BRAZIL ***

PUT PARAMETERS

LAND AREA	3286170 SQ MI
LATITUDE OF COUNTRY'S GEOGRAPHICAL CENTER	-14° **** DEG
ASSUMED COST OF SATELLITE POWER ($/WATT-YEAR)	$50000.
DISCOUNT FACTOR	10.0%
NO. OF TV-TRANSMIT/AUDIO-RECEIVE (MASTER) STATIONS	1
NO. OF TV-RECEIVE/AUDIO-TRANSMIT (SLAVE) STATIONS	1800
NO. OF TV CHANNELS PER MASTER STATION	4
NO. OF TV CHANNELS PER SLAVE STATION	4
SIGNAL-TO-NOISE RATIO REQUIRED FOR TV	43 DB
SIGNAL-TO-NOISE RATIO REQUIRED FOR AUDIO	43 DB

TPUT PARAMETERS

MASTER STATION

ANTENNA:	DIAMETER	49.6 FT	UNIT COST	$ 554768.
RCVR PRE-AMP:	NOISE TEMP	20. DEG K	UNIT COST	$ 60000
TXMTR PWR AMP:	OUTPUT PWR	350.0 W	UNIT COST	$ 17000
INITIAL CAPITAL COST PER STATION				$ 980956
PRESENT WORTH OF TEN-YEAR ANNUAL COST STREAM				$ 2112689

SLAVE STATION

ANTENNA:	DIAMETER	11.8 FT	UNIT COST	$ 6466.
RCVR PRE-AMP:	NOISE TEMP	180. DEG K	UNIT COST	$ 7000
TXMTR PWR AMP	OUTPUT PWR	30.0 W	UNIT COST	$ 6000
INITIAL CAPITAL COST PER STATION				$ 14411
PRESENT WORTH OF TEN-YEAR ANNUAL COST STREAM				$ 25337

SATELLITE

SATELLITE ANTENNA N-S DIAMETER	4.3'	**** FT
SATELLITE ANTENNA E-W DIAMETER	4.2'	-0.0 FT
MAXIMUM SLANT RANGE FOR TRANSMISSION		23081.7 MI
POWER CHARGED PER TV CHANNEL		17.13 W
POWER CHARGED PER AUDIO CHANNEL		0.0124972 W
TOTAL COST PER YEAR OF SATELLITE POWER		$ 3519270
PRESENT WORTH OF TEN-YEAR ANNUAL COST STREAM		$ 21622384

TOTAL INITIAL CAPITAL COST (NOT INCLUDING SATELLITE COSTS)	$ 16280752.
PRESENT WORTH OF TOTAL-SYSTEM TEN-YEAR COST	$ 69342720.
ANNUAL COST OF TOTAL SYSTEM PER SLAVE STATION	$ 6241.
ANNUAL COST OF TOTAL SYSTEM PER SLAVE STATION PER TV CHANNEL	$ 1560.

NK CALCULATIONS

TV UP-LINK (2.5 GHZ)	
OUTPUT PWR PER CHANNEL OF MASTER STATION PWR AMP	23.4 DB
MASTER STATION ANTENNA GAIN	49.4 DB
PATH LOSS	-191.6 DB
SATELLITE ANTENNA GAIN	27.6 DB
EQUIVALENT INPUT NOISE PWR DENSITY AT SAT. RCVR	196.6 DB
NOISE BANDWIDTH (25.1 MHZ)	-74.0 DB
UP-LINK CNR	31.4 DB
TV DOWN-LINK (2.5 GHZ)	
OUTPUT POWER OF SATELLITE TRANSPONDER	12.3 DB
SATELLITE ANTENNA GAIN	24.6 DB
PATH LOSS	-191.8 DB
SLAVE STATION ANTENNA GAIN	36.9 DB
EQUIVALENT INPUT NOISE PWR DENSITY AT SLAVE STATION RCVR	205.0 DB
NOISE BANDWIDTH	-74.0 DB
DOWN-LINK CNR	13.1 DB
TV TOTAL CNR	13.0 DB
TV TOTAL SNR (=6*(((B/2F)-1)**2)*(C/N)*(B/F)*KP)	42.9 DB

WHERE B = RF BANDWIDTH; F = HIGHEST BASEBAND FREQUENCY;
C/N = TV TOTAL CNR; KP = A NOISE WEIGHTING FACTOR

AUDIO UP-LINK (2.5 GHZ)	
OUTPUT POWER PER CHANNEL AT SLAVE STA. PWR. AMP.	13.8 DB
SLAVE STATION ANTENNA GAIN	36.9 DB
PATH LOSS	-191.8 DB
SATELLITE ANTENNA GAIN	24.6 DB
EQUIVALENT INPUT NOISE PWR DENSITY AT SAT. RCVR	196.6 DB
NOISE BANDWIDTH (0.100 MHZ)	-50.0 DB
UP-LINK CNR	30.1 DB
BACK-OFF OF SATELLITE TRANSPONDER	10.0 DB
CNR FROM INTERMODULATION IN SATELLITE TWT	16.9 DB
AUDIO DOWN-LINK (2.5 GHZ)	
OUTPUT PWR PER CHANNEL AT SAT. TRANSPONDER	-29.0 DB
SATELLITE ANTENNA GAIN	24.6 DB
PATH LOSS	-191.6 DB
MASTER STATION ANTENNA GAIN	49.4 DB
EQUIVALENT INPUT NOISE PWR DENSITY AT MASTER STA.RCVR	212.1 DB
NOISE BANDWIDTH	-50.0 DB
DOWN-LINK CNR	15.4 DB
AUDIO TOTAL CNR	13.0 DB
AUDIO TOTAL SNR (=3*(((B/2F)-1)**2)*(C/N)*(B/F)*(1/KP'))	43.5 DB

WHERE KP' IS THE PEAK-TO-AVERAGE POWER RATIO FOR A
SINGLE VOICE SIGNAL; OTHER PARAMETERS AS ABOVE

*** BRAZIL ***

INPUT PARAMETERS

LAND AREA	3286170 SQ MI
LATITUDE OF COUNTRY'S GEOGRAPHICAL CENTER	-14° **** DEG
ASSUMED COST OF SATELLITE POWER ($/WATT-YEAR)	$50000.
DISCOUNT FACTOR	10.0%
NO. OF TV-TRANSMIT/AUDIO-RECEIVE (MASTER) STATIONS	28
NO. OF TV-RECEIVE/AUDIO-TRANSMIT (SLAVE) STATIONS	6500
NO. OF TV CHANNELS PER MASTER STATION	2
NO. OF TV CHANNELS PER SLAVE STATION	12
SIGNAL-TO-NOISE RATIO REQUIRED FOR TV	43 DB
SIGNAL-TO-NOISE RATIO REQUIRED FOR AUDIO	43 DB

OUTPUT PARAMETERS

MASTER STATION

ANTENNA:	DIAMETER	45.4 FT	UNIT COST	$ 526790.
RCVR PRE-AMP:	NOISE TEMP	20. DEG K	UNIT COST	$ 80000
TXMTR PWR AMP:	OUTPUT PWR	350.0 W	UNIT COST	$ 17000
INITIAL CAPITAL COST PER STATION				$ 610302
PRESENT WORTH OF TEN-YEAR ANNUAL COST STREAM				$ 1313421

SLAVE STATION

ANTENNA:	DIAMETER	12.0 FT	UNIT COST	$ 2606.
RCVR PRE-AMP:	NOISE TEMP	180. DEG K	UNIT COST	$ 7000
TXMTR PWR AMP	OUTPUT PWR	30.0 W	UNIT COST	$ 6000
INITIAL CAPITAL COST PER STATION				$ 24119
PRESENT WORTH OF TEN-YEAR ANNUAL COST STREAM				$ 35741

SATELLITE

SATELLITE ANTENNA N-S DIAMETER	4.3' **** FT
SATELLITE ANTENNA E-W DIAMETER	4.2' -0.0 FT
MAXIMUM SLANT RANGE FOR TRANSMISSION	23081.7 MI
POWER CHARGED PER TV CHANNEL	18.38 W
POWER CHARGED PER AUDIO CHANNEL	0.0149460 W
TOTAL COST PER YEAR OF SATELLITE POWER	$ 12200186
PRESENT WORTH OF TEN-YEAR ANNUAL COST STREAM	$ 74957920

TOTAL INITIAL CAPITAL COST $ 80262352.
(NOT INCLUDING SATELLITE COSTS)

PRESENT WORTH OF TOTAL-SYSTEM TEN-YEAR COST	$ 344055296.
ANNUAL COST OF TOTAL SYSTEM PER SLAVE STATION	$ 8575.
ANNUAL COST OF TOTAL SYSTEM PER SLAVE STATION PER TV CHANNEL	$ 715.

BRAZIL (CON'T)

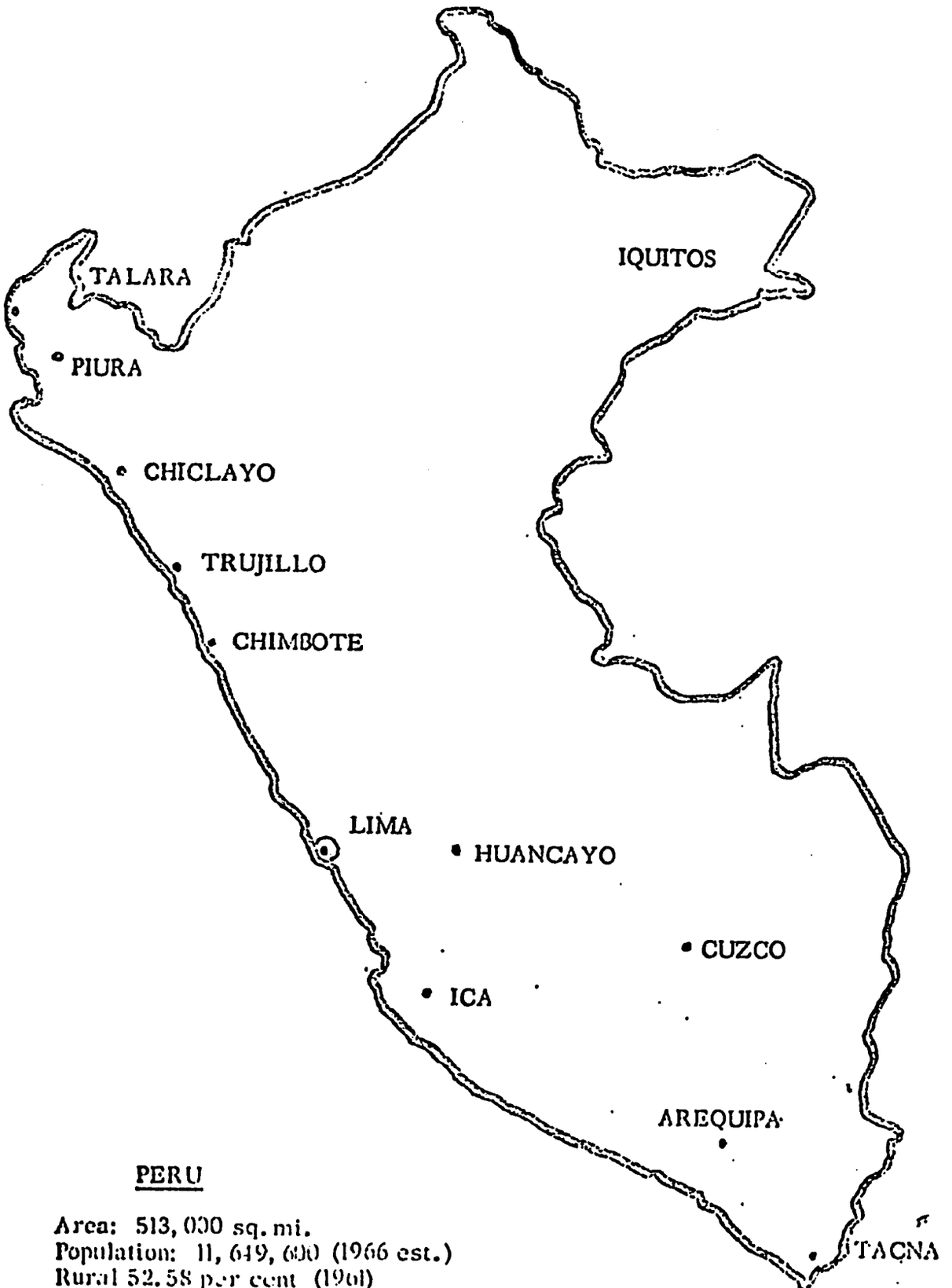
INK CALCULATIONS

TV UP-LINK (2.5 GHZ)	
OUTPUT PWR PER CHANNEL OF MASTER STATION PWR AMP	24.2
MASTER STATION ANTENNA GAIN	48.6
PATH LOSS	-191.6
SATELLITE ANTENNA GAIN	27.6
EQUIVALENT INPUT NOISE PWR DENSITY AT SAT. RCVR	196.6
NOISE BANDWIDTH (25.1 MHZ)	-74.0
UP-LINK CNR	31.4
TV DOWN-LINK (2.5 GHZ)	
OUTPUT POWER OF SATELLITE TRANSPONDER	12.6
SATELLITE ANTENNA GAIN	24.6
PATH LOSS	-191.8
SLAVE STATION ANTENNA GAIN	36.6
EQUIVALENT INPUT NOISE PWR DENSITY AT SLAVE STATION RCVR	205.0
NOISE BANDWIDTH	-74.0
DOWN-LINK CNR	13.1
TV TOTAL CNR	13.0
TV TOTAL SNR (=6*(((B/2F)-1)**2)*(C/N)*(B/F)*KP)	42.9

WHERE B = RF BANDWIDTH; F = HIGHEST BASEBAND FREQUENCY;
C/N = TV TOTAL CNR; KP = A NOISE WEIGHTING FACTOR

AUDIO UP-LINK (2.5 GHZ)	
OUTPUT POWER PER CHANNEL AT SLAVE STA. PWR. AMP.	13.8
SLAVE STATION ANTENNA GAIN	36.6
PATH LOSS	-191.8
SATELLITE ANTENNA GAIN	24.6
EQUIVALENT INPUT NOISE PWR DENSITY AT SAT. RCVR	196.6
NOISE BANDWIDTH (0.100 MHZ)	-50.0
UP-LINK CNR	29.8
BACK-OFF OF SATELLITE TRANSPONDER	10.0
CNR FROM INTERMODULATION IN SATELLITE TWT	16.9
AUDIO DOWN-LINK (2.5 GHZ)	
OUTPUT PWR PER CHANNEL AT SAT. TRANSPONDER	-28.3
SATELLITE ANTENNA GAIN	24.6
PATH LOSS	-191.6
MASTER STATION ANTENNA GAIN	48.6
EQUIVALENT INPUT NOISE PWR DENSITY AT MASTER STA.RCVR	212.1
NOISE BANDWIDTH	-50.0
DOWN-LINK CNR	15.4
AUDIO TOTAL CNR	13.0
AUDIO TOTAL SNR (=3*(((B/2F)-1)**2)*(C/N)*(B/F)*(1/KP'))	43.5

WHERE KP' IS THE PEAK-TO-AVERAGE POWER RATIO FOR A
SINGLE VOICE SIGNAL; OTHER PARAMETERS AS ABOVE



PERU

Area: 513,000 sq. mi.
Population: 11,649,600 (1966 est.)
Rural 52.58 per cent (1961)
47.2 per cent (1980 projected)

*** PERU ***

T PARAMETERS

ANC AREA	115000 SQ MI
ATITUDE OF CCUNTRY'S GECGRAPHICAL CENTER	-9.0 DEG
SSUMED COST OF SATELLITE POWER ($/WATT-YEAR)	$50000.
ISCCUNT FACTOR	10.0%
O. OF TV-TRANSMIT/ALDIC-RECEIVE (MASTER) STATICNS	1
C. OF TV-RECEIVE/ALCIO-TRANSMIT (SLAVE) STATICNS	35
O. OF TV CHANNELS PER MASTER STATICN	4
O. OF TV CHANNELS PER SLAVE STATICN	4
IGNAL-TO-NOISE RATIO RECUIRED FOR TV	43 DB
IGNAL-TO-NOISE RATIO RECUIRED FCR AUDIO	43 DB

UT PARAMETERS

MASTER STATION

ANTENNA:	DIAMETER	24.2 FT	UNIT COST	$ 47542.
RCVR PRE-AMP:	NOISE TEMP	40. DEG K	UNIT CCST	$ 4000
TXMTR PWR AMP:	CUTPUT PWR	1CC.0 W	UNIT CCST	$ 1000
INITIAL CAPITAL CCST PER STATION				$ 16155
PRESENT WORTH OF TEN-YEAR ANNUAL CCST STREAM				$ 36157

SLAVE STATION

ANTENNA:	CIAMETER	12.0 FT	UNIT COST	$ 2606.
RCVR PRE-AMP:	NOISE TEMP	180. DEG K	UNIT COST	$ 700
TXMTR PWR AMP	OUTPUT PWR	5.0 W	UNIT COST	$ 200
INITIAL CAPITAL CCST PER STATION				$ 1157
PRESENT WORTH OF TEN-YEAR ANNUAL COST STREAM				$ 1897

SATELLITE

SATELLITE ANTENNA N-S DIAMETER	9.0'	**** F
SATELLITE ANTENNA E-W DIAMETER	16.5'	-0.0 F
MAXIMUM SLANT RANGE FCR TRANSMISSICN		22532.4 M
POWER CHARGED PER TV CHANNEL		3.12
PCWER CHARGED PER AUCIO CHANNEL		0.0136906
TOTAL COST PER YEAR CF SATELLITE PCWER		$ 64644
PRESENT WORTH OF TEN-YEAR ANNUAL COST STREAM		$ 397176

TOTAL INITIAL CAPITAL CCST (NOT INCLUDING SATELLITE COSTS)	$ 2567055
PRESENT WORTH CF TOTAL-SYSTEM TEN-YEAR CCST	$ 11070911
ANNUAL COST OF TOTAL SYSTEM PER SLAVE STATICN	$ 5052
ANNUAL CCST OF TOTAL SYSTEM PER SLAVE STATION PER TV CHANNEL	$ 1263

PERU (CON'T)

\K CALCULATIONS

TV UP-LINK (2.5 GHZ)	
OUTPUT PWR PER CHANNEL OF MASTER STATION PWR AMP	18.0 DB
MASTER STATION ANTENNA GAIN	43.2 DB
PATH LOSS	-191.5 DB
SATELLITE ANTENNA GAIN	35.2 DB
EQUIVALENT INPUT NOISE PWR DENSITY AT SAT. RCVR	196.6 DB
NOISE BANDWIDTH (25.1 MHZ)	-74.0 DB
UP-LINK CNR	27.4 DB
TV DOWN-LINK (2.5 GHZ)	
OUTPUT POWER OF SATELLITE TRANSPONDER	4.9 DB
SATELLITE ANTENNA GAIN	32.2 DB
PATH LOSS	-191.6 DB
SLAVE STATION ANTENNA GAIN	36.6 DB
EQUIVALENT INPUT NOISE PWR DENSITY AT SLAVE STATION RCVR	205.0 DB
NOISE BANDWIDTH	-74.0 DB
DOWN-LINK CNR	13.2 DB
TV TOTAL CNR	13.0 DB
TV TOTAL SNR (=6*(((B/2F)-1)**2)*(C/N)*(B/F)*KP)	42.9 DB
WHERE B = RF BANDWIDTH; F = HIGHEST BASEBAND FREQUENCY; C/N = TV TOTAL CNR; KP = A NOISE WEIGHTING FACTOR	
AUDIO UP-LINK (2.5 GHZ)	
OUTPUT POWER PER CHANNEL AT SLAVE STA. PWR. AMP.	6.0 DB
SLAVE STATION ANTENNA GAIN	36.6 DB
PATH LOSS	-191.6 DB
SATELLITE ANTENNA GAIN	32.2 DB
EQUIVALENT INPUT NOISE PWR DENSITY AT SAT. RCVR	196.6 DB
NOISE BANDWIDTH (0.100 MHZ)	-50.0 DB
UP-LINK CNR	29.8 DB
BACK-OFF OF SATELLITE TRANSPONDER	10.0 DB
CNR FROM INTERMODULATION IN SATELLITE TWT	16.9 DB
AUDIO DOWN-LINK (2.5 GHZ)	
OUTPUT PWR PER CHANNEL AT SAT. TRANSPONDER	-28.6 DB
SATELLITE ANTENNA GAIN	32.2 DB
PATH LOSS	-191.5 DB
MASTER STATION ANTENNA GAIN	43.2 DB
EQUIVALENT INPUT NOISE PWR DENSITY AT MASTER STA.RCVR	210.3 DB
NOISE BANDWIDTH	-50.0 DB
DOWN-LINK CNR	15.4 DB
AUDIO TOTAL CNR	13.0 DB
AUDIO TOTAL SNR (=3*(((B/2F)-1)**2)*(C/N)*(B/F)*(1/KP'))	43.5 DB
WHERE KP' IS THE PEAK-TO-AVERAGE POWER RATIO FOR A SINGLE VOICE SIGNAL; OTHER PARAMETERS AS ABOVE	

*** PERU ***

PARAMETERS

NC AREA	115000 SQ MI
TITUDE OF COUNTRY'S GEOGRAPHICAL CENTER	-9.0 DEG
SUMED COST OF SATELLITE POWER ($/WATT-YEAR)	$50000.
SCOUNT FACTOR	10.0%
. OF TV-TRANSMIT/AUDIO-RECEIVE (MASTER) STATIONS	12
. OF TV-RECEIVE/AUDIO-TRANSMIT (SLAVE) STATIONS	7950
. OF TV CHANNELS PER MASTER STATION	2
. OF TV CHANNELS PER SLAVE STATION	12
GNAL-TO-NOISE RATIO REQUIRED FOR TV	43 DB
GNAL-TO-NOISE RATIO REQUIRED FOR AUDIO	43 DB

T PARAMETERS

ASTER STATION

ANTENNA:	DIAMETER	39.8 FT	UNIT COST	$ 145436.
RCVR PRE-AMP:	NOISE TEMP	40. DEG K	UNIT COST	$ 40000
TXMTR PWR AMP:	OUTPUT PWR	30.0 W	UNIT COST	$ 6000
INITIAL CAPITAL COST PER STATION				$ 196140
PRESENT WORTH OF TEN-YEAR ANNUAL COST STREAM				$ 393866

LAVE STATION

ANTENNA:	DIAMETER	10.8 FT	UNIT COST	$ 1475.
RCVR PRE-AMP:	NOISE TEMP	320. DEG K	UNIT COST	$ 1000
TXMTR PWR AMP	OUTPUT PWR	5.0 W	UNIT COST	$ 2000
INITIAL CAPITAL COST PER STATION				$ 17097
PRESENT WORTH OF TEN-YEAR ANNUAL COST STREAM				$ 19147

ATELLITE

SATELLITE ANTENNA N-S DIAMETER	9.0'	**** FT
SATELLITE ANTENNA E-W DIAMETER	11.5'	-0.0 FT
MAXIMUM SLANT RANGE FOR TRANSMISSION		22532.4 MI
POWER CHARGED PER TV CHANNEL		6.55 W
POWER CHARGED PER AUDIO CHANNEL		0.0055486 W
TOTAL COST PER YEAR OF SATELLITE POWER		$ 4463622
PRESENT WORTH OF TEN-YEAR ANNUAL COST STREAM		$ 27424480

OTAL INITIAL CAPITAL COST $ 23795872.
(NOT INCLUDING SATELLITE COSTS)

RESENT WORTH OF TOTAL-SYSTEM TEN-YEAR COST	$ 184375936.
NNUAL COST OF TOTAL SYSTEM PER SLAVE STATION	$ 3757.
NNUAL COST OF TOTAL SYSTEM PER SLAVE STATION PER TV CHANNEL	$ 313.

PFFU (CON'T)

CALCULATIONS

TV UP-LINK (2.5 GHZ)	
OUTPUT PWR PER CHANNEL OF MASTER STATION PWR AMP	13.5 DB
MASTER STATION ANTENNA GAIN	47.5 DB
PATH LOSS	-191.5 DB
SATELLITE ANTENNA GAIN	35.2 DB
EQUIVALENT INPUT NOISE PWR DENSITY AT SAT. RCVR	196.6 DB
NOISE BANDWIDTH (25.1 MHZ)	-74.0 DB
UP-LINK CNR	27.2 DB
TV DOWN-LINK (2.5 GHZ)	
OUTPUT POWER OF SATELLITE TRANSPONDER	8.2 DB
SATELLITE ANTENNA GAIN	32.2 DB
PATH LOSS	-191.6 DB
SLAVE STATION ANTENNA GAIN	35.7 DB
EQUIVALENT INPUT NOISE PWR DENSITY AT SLAVE STATION RCVR	202.7 DB
NOISE BANDWIDTH	-74.0 DB
DOWN-LINK CNR	13.2 DB
TV TOTAL CNR	13.0 DB
TV TOTAL SNR (=6*(((B/2F)-1)**2)*(C/N)*(B/F)*KP)	42.9 DB
WHERE B = RF BANDWIDTH; F = HIGHEST BASEBAND FREQUENCY; C/N = TV TOTAL CNR; KP = A NOISE WEIGHTING FACTOR	
AUDIO UP-LINK (2.5 GHZ)	
OUTPUT POWER PER CHANNEL AT SLAVE STA. PWR. AMP.	6.0 DB
SLAVE STATION ANTENNA GAIN	35.7 DB
PATH LOSS	-191.6 DB
SATELLITE ANTENNA GAIN	32.2 DB
EQUIVALENT INPUT NOISE PWR DENSITY AT SAT. RCVR	196.6 DB
NOISE BANDWIDTH (0.100 MHZ)	-50.0 DB
UP-LINK CNR	28.9 DB
BACK-OFF OF SATELLITE TRANSPONDER	11.0 DB
CNR FROM INTERMODULATION IN SATELLITE TWT	18.0 DB
AUDIO DOWN-LINK (2.5 GHZ)	
OUTPUT PWR PER CHANNEL AT SAT. TRANSPONDER	-33.6 DB
SATELLITE ANTENNA GAIN	32.2 DB
PATH LOSS	-191.5 DB
MASTER STATION ANTENNA GAIN	47.5 DB
EQUIVALENT INPUT NOISE PWR DENSITY AT MASTER STA.RCVR	210.3 DB
NOISE BANDWIDTH	-50.0 DB
DOWN-LINK CNR	14.8 DB
AUDIO TOTAL CNR	13.0 DB
AUDIO TOTAL SNR (=3*(((B/2F)-1)**2)*(C/N)*(B/F)*(1/KP'))	43.5 DB
WHERE KP' IS THE PEAK-TO-AVERAGE POWER RATIO FOR A SINGLE VOICE SIGNAL; OTHER PARAMETERS AS ABOVE	

MEXICO

Area: 760,373 sq. mi.
Population: 45,671,000 (1967)
Rural 43.0 per cent (1967)
29.3 per cent (1980 projected)

*** MEXICO ***

'UT PARAMETERS

LAND AREA	760373 SQ
LATITUDE OF COUNTRY'S GEOGRAPHICAL CENTER	24.0 D
ASSUMED COST OF SATELLITE POWER ($/WATT-YEAR)	$5000
DISCOUNT FACTOR	10.
NO. OF TV-TRANSMIT/AUDIO-RECEIVE (MASTER) STATIONS	
NO. OF TV-RECEIVE/AUDIO-TRANSMIT (SLAVE) STATIONS	60
NO. OF TV CHANNELS PER MASTER STATION	
NO. OF TV CHANNELS PER SLAVE STATION	
SIGNAL-TO-NOISE RATIO REQUIRED FOR TV	43
SIGNAL-TO-NOISE RATIO REQUIRED FOR AUDIO	43

'PUT PARAMETERS

MASTER STATION

ANTENNA:	DIAMETER	51.1 FT	UNIT COST	$ 56692
RCVR PRE-AMP:	NOISE TEMP	20. DEG K	UNIT COST	$ 800
TXMTR PWR AMP:	OUTPUT PWR	100.0 W	UNIT COST	$ 100
INITIAL CAPITAL COST PER STATION				$ 9654
PRESENT WORTH OF TEN-YEAR ANNUAL COST STREAM				$ 20715

SLAVE STATION

ANTENNA:	DIAMETER	10.8 FT	UNIT COST	$ 147
RCVR PRE-AMP:	NOISE TEMP	320. DEG K	UNIT COST	$ 10
TXMTR PWR AMP	OUTPUT PWR	10.0 W	UNIT COST	$ 35
INITIAL CAPITAL COST PER STATION				$ 72
PRESENT WORTH OF TEN-YEAR ANNUAL COST STREAM				$ 92

SATELLITE

SATELLITE ANTENNA N-S DIAMETER	****
SATELLITE ANTENNA E-W DIAMETER	-0.0
MAXIMUM SLANT RANGE FOR TRANSMISSION	23166.1
POWER CHARGED PER TV CHANNEL	12.81
POWER CHARGED PER AUDIO CHANNEL	0.0043461
TOTAL COST PER YEAR OF SATELLITE POWER	$ 26677
PRESENT WORTH OF TEN-YEAR ANNUAL COST STREAM	$ 163908

TOTAL INITIAL CAPITAL COST $ 1601001
(NOT INCLUDING SATELLITE COSTS)

PRESENT WORTH OF TOTAL-SYSTEM TEN-YEAR COST	$ 7422798
ANNUAL COST OF TOTAL SYSTEM PER SLAVE STATION	$ 198
ANNUAL COST OF TOTAL SYSTEM PER SLAVE STATION PER TV CHANNEL	$ 49

MEXICO (CON'T)

LINK CALCULATIONS

TV UP-LINK (2.5 GHZ)	
OUTPUT PWR PER CHANNEL OF MASTER STATION PWR AMP	18.0
MASTER STATION ANTENNA GAIN	49.6
PATH LOSS	-191.7
SATELLITE ANTENNA GAIN	32.4
EQUIVALENT INPUT NOISE PWR DENSITY AT SAT. RCVR	196.6
NOISE BANDWIDTH (25.1 MHZ)	-74.0
UP-LINK CNR	31.0
TV DOWN-LINK (2.5 GHZ)	
OUTPUT POWER OF SATELLITE TRANSPONDER	11.1
SATELLITE ANTENNA GAIN	29.4
PATH LOSS	-191.8
SLAVE STATION ANTENNA GAIN	35.7
EQUIVALENT INPUT NOISE PWR DENSITY AT SLAVE STATION RCVR	202.7
NOISE BANDWIDTH	-74.0
DOWN-LINK CNR	13.1
TV TOTAL CNR	13.0
TV TOTAL SNR (=6*(((B/2F)-1)**2)*(C/N)*(B/F)*KP)	42.9
WHERE B = RF BANDWIDTH; F = HIGHEST BASEBAND FREQUENCY; C/N = TV TOTAL CNR; KP = A NOISE WEIGHTING FACTOR	
AUDIO UP-LINK (2.5 GHZ)	
OUTPUT POWER PER CHANNEL AT SLAVE STA. PWR. AMP.	9.0
SLAVE STATION ANTENNA GAIN	35.7
PATH LOSS	-191.8
SATELLITE ANTENNA GAIN	29.4
EQUIVALENT INPUT NOISE PWR DENSITY AT SAT. RCVR	196.6
NOISE BANDWIDTH (0.100 MHZ)	-50.0
UP-LINK CNR	28.9
BACK-OFF OF SATELLITE TRANSPONDER	11.0
CNR FROM INTERMODULATION IN SATELLITE TWT	18.0
AUDIO DOWN-LINK (2.5 GHZ)	
OUTPUT PWR PER CHANNEL AT SAT. TRANSPONDER	-34.6
SATELLITE ANTENNA GAIN	29.4
PATH LOSS	-191.7
MASTER STATION ANTENNA GAIN	49.6
EQUIVALENT INPUT NOISE PWR DENSITY AT MASTER STA.RCVR	212.1
NOISE BANDWIDTH	-50.0
DOWN-LINK CNR	14.8
AUDIO TOTAL CNR	13.0
AUDIO TOTAL SNR (=3*(((B/2F)-1)**2)*(C/N)*(B/F)*(1/KP'))	43.5
WHERE KP' IS THE PEAK-TO-AVERAGE POWER RATIO FOR A SINGLE VOICE SIGNAL; OTHER PARAMETERS AS ABOVE	

*** MEXICO ***

PUT PARAMETERS

LAND AREA	760373 SQ MI
LATITUDE OF COUNTRY'S GEOGRAPHICAL CENTER	24.0 DEG
ASSUMED COST OF SATELLITE POWER ($/WATT-YEAR)	$50000.
DISCOUNT FACTOR	10.0%
NO. OF TV-TRANSMIT/AUDIO-RECEIVE (MASTER) STATIONS	22
NO. OF TV-RECEIVE/AUDIO-TRANSMIT (SLAVE) STATIONS	11000
NO. OF TV CHANNELS PER MASTER STATION	2
NO. OF TV CHANNELS PER SLAVE STATION	12
SIGNAL-TO-NOISE RATIO REQUIRED FOR TV	43 DB
SIGNAL-TO-NOISE RATIO REQUIRED FOR AUDIO	43 DB

TPLT PARAMETERS

MASTER STATION

ANTENNA:	DIAMETER	44.7 FT	UNIT COST	$ 523045.
RCVR PRE-AMP:	NOISE TEMP	20. DEG K	UNIT COST	$ 80000
TXMTR PWR AMP:	OUTPUT PWR	10.0 W	UNIT COST	$ 3500
INITIAL CAPITAL COST PER STATION				$ 596386
PRESENT WORTH OF TEN-YEAR ANNUAL COST STREAM				$ 1274759

SLAVE STATION

ANTENNA:	DIAMETER	10.7 FT	UNIT COST	$ 1400.
RCVR PRE-AMP:	NOISE TEMP	320. DEG K	UNIT COST	$ 1000
TXMTR PWR AMP	OUTPUT PWR	5.0 W	UNIT COST	$ 2000
INITIAL CAPITAL COST PER STATION				$ 16935
PRESENT WORTH OF TEN-YEAR ANNUAL COST STREAM				$ 18865

SATELLITE

SATELLITE ANTENNA N-S DIAMETER	9.6 FT
SATELLITE ANTENNA E-W DIAMETER	5.7 FT
MAXIMUM SLANT RANGE FOR TRANSMISSION	23166.1 MI
POWER CHARGED PER TV CHANNEL	13.27 W
POWER CHARGED PER AUDIO CHANNEL	0.0065686 W
TOTAL COST PER YEAR OF SATELLITE POWER	$ 8834034
PRESENT WORTH OF TEN-YEAR ANNUAL COST STREAM	$ 54276288

TOTAL INITIAL CAPITAL COST $ 41007328.
(NOT INCLUDING SATELLITE COSTS)

PRESENT WORTH OF TOTAL-SYSTEM TEN-YEAR COST	$ 289843712.
ANNUAL COST OF TOTAL SYSTEM PER SLAVE STATION	$ 4269.
ANNUAL COST OF TOTAL SYSTEM PER SLAVE STATION PER TV CHANNEL	$ 356.

KK CALCULATIONS

TV UP-LINK (6.0 GHZ)	
OUTPUT PWR PER CHANNEL OF MASTER STATION PWR AMP	8.7 DB
MASTER STATION ANTENNA GAIN	56.1 DB
PATH LOSS	-199.3 DB
SATELLITE ANTENNA GAIN	40.0 DB
EQUIVALENT INPUT NOISE PWR DENSITY AT SAT. RCVR	196.6 DB
NOISE BANDWIDTH (25.1 MHZ)	-74.0 DB
UP-LINK CNR	28.2 DB
TV DOWN-LINK (2.5 GHZ)	
OUTPUT POWER OF SATELLITE TRANSPONDER.	11.2 DB
SATELLITE ANTENNA GAIN	29.4 DB
PATH LOSS	-191.8 DB
SLAVE STATION ANTENNA GAIN	35.6 DB
EQUIVALENT INPUT NOISE PWR DENSITY AT SLAVE STATION RCVR	202.7 DB
NOISE BANDWIDTH	-74.0 DB
DOWN-LINK CNR	13.1 DB
TV TOTAL CNR	13.0 DB
TV TOTAL SNR (=6*(((B/2F)-1)2)*(C/N)*(B/F)*KP)**	42.9 DB
WHERE B = RF BANDWIDTH; F = HIGHEST BASEBAND FREQUENCY; C/N = TV TOTAL CNR; KP = A NOISE WEIGHTING FACTOR	
AUDIO UP-LINK (6.0 GHZ)	
OUTPUT POWER PER CHANNEL AT SLAVE STA. PWR. AMP.	6.0 DB
SLAVE STATION ANTENNA GAIN	43.2 DB
PATH LOSS	-199.5 DB
SATELLITE ANTENNA GAIN	37.0 DB
EQUIVALENT INPUT NOISE PWR DENSITY AT SAT. RCVR	196.6 DB
NOISE BANDWIDTH (0.100 MHZ)	-50.0 DB
UP-LINK CNR	33.4 DB
BACK-OFF OF SATELLITE TRANSPONDER	10.0 DB
CNR FROM INTERMODULATION IN SATELLITE TWT	16.9 DB
AUDIO DOWN-LINK (2.2 GHZ)	
OUTPUT PWR PER CHANNEL AT SAT. TRANSPONDER	-31.8 DB
SATELLITE ANTENNA GAIN	28.3 DB
PATH LOSS	-190.6 DB
MASTER STATION ANTENNA GAIN	47.4 DB
EQUIVALENT INPUT NOISE PWR DENSITY AT MASTER STA.RCVR	212.1 DB
NOISE BANDWIDTH	-50.0 DB
DOWN-LINK CNR	15.3 DB
AUDIO TOTAL CNR	13.0 DB
AUDIO TOTAL SNR (=3*(((B/2F)-1)2)*(C/N)*(B/F)*(1/KP'))**	43.5 DB
WHERE KP' IS THE PEAK-TO-AVERAGE POWER RATIO FOR A SINGLE VOICE SIGNAL; OTHER PARAMETERS AS ABOVE	

COLOMBIA

Area: 439,828 sq. mi.
Population: 18,100,000 (1965)
Rural 53.9 per cent (1960)
37.9 per cent (1980 projected)

*** COLOMBIA ***

INPUT PARAMETERS

LAND AREA	439828 S
LATITUDE OF COUNTRY'S GEOGRAPHICAL CENTER	5.0
ASSUMED COST OF SATELLITE POWER ($/WATT-YEAR)	$50
DISCOUNT FACTOR	1
NO. OF TV-TRANSMIT/AUDIO-RECEIVE (MASTER) STATIONS	
NO. OF TV-RECEIVE/AUDIO-TRANSMIT (SLAVE) STATIONS	
NO. OF TV CHANNELS PER MASTER STATION	
NO. OF TV CHANNELS PER SLAVE STATION	
SIGNAL-TO-NOISE RATIO REQUIRED FOR TV	4
SIGNAL-TO-NOISE RATIO REQUIRED FOR AUDIO	4

OUTPUT PARAMETERS

MASTER STATION

ANTENNA:	DIAMETER	28.4 FT	UNIT COST	$ 68
RCVR PRE-AMP:	NOISE TEMP	90. DEG K	UNIT COST	$ 1
TXMTR PWR AMP:	OUTPUT PWR	10.0 W	UNIT COST	$
INITIAL CAPITAL COST PER STATION				$ 13
PRESENT WORTH OF TEN-YEAR ANNUAL COST STREAM				$ 24

SLAVE STATION

ANTENNA:	DIAMETER	12.2 FT	UNIT COST	$ 7
RCVR PRE-AMP:	NOISE TEMP	180. DEG K	UNIT COST	$
TXMTR PWR AMP	OUTPUT PWR	0.5 W	UNIT COST	$
INITIAL CAPITAL COST PER STATION				$ 1
PRESENT WORTH OF TEN-YEAR ANNUAL COST STREAM				$ 2

SATELLITE

SATELLITE ANTENNA N-S DIAMETER	9.4
SATELLITE ANTENNA E-W DIAMETER	13.
MAXIMUM SLANT RANGE FOR TRANSMISSION	22419.
POWER CHARGED PER TV CHANNEL	2.
POWER CHARGED PER AUDIO CHANNEL	0.02126
TOTAL COST PER YEAR OF SATELLITE POWER	$ 46
PRESENT WORTH OF TEN-YEAR ANNUAL COST STREAM	$ 287

TOTAL INITIAL CAPITAL COST (NOT INCLUDING SATELLITE COSTS)	$ 20230
PRESENT WORTH OF TOTAL-SYSTEM TEN-YEAR COST	$ 78910
ANNUAL COST OF TOTAL SYSTEM PER SLAVE STATION	$ 66
ANNUAL COST OF TOTAL SYSTEM PER SLAVE STATION PER TV CHANNEL	$ 16

COLCFBIA(CCN'T)

LINK CALCULATICNS

TV UP-LINK (6.0 GHZ)	
OUTPUT PWR PER CHANNEL OF MASTER STATICN PWR AMP	8.0 DB
MASTER STATICN ANTENNA GAIN	52.1 DB
PATH LCSS	-199.1 DB
SATELLITE ANTENNA GAIN	43.6 DB
EQUIVALENT INPUT NCISE PWR DENSITY AT SAT. RCVR	196.6 DB
NOISE BANDWIDTH (25.1 MHZ)	-74.0 DB
UP-LINK CNR	27.2 DB
TV DOWN-LINK (2.5 GHZ)	
OUTPUT POWER OF SATELLITE TRANSPONDER	3.5 DB
SATELLITE ANTENNA GAIN	33.0 DB
PATH LOSS	-191.6 DB
SLAVE STATICN ANTENNA GAIN	37.2 DB
EQUIVALENT INPUT NCISE PWR DENSITY AT SLAVE STATICN RCVR	205.0 DB
NOISE BANDWIDTH	-74.0 DB
DOWN-LINK CNR	13.2 DB
TV TOTAL CNR	13.0 DB
TV TOTAL SNR (=6*(((B/2F)-1)**2)*(C/N)*(B/F)*KP)	42.9 DB
WHERE B = RF BANDWIDTH; F = HIGHEST BASEBAND FREQUENCY; C/N = TV TCTAL CNR; KP = A NCISE WEIGHTING FACTOR	
AUDIO UP-LINK (6.0 GHZ)	
OUTPUT POWER PER CHANNEL AT SLAVE STA. PWR. AMP.	-4.0 DB
SLAVE STATION ANTENNA GAIN	44.8 DB
PATH LOSS	-199.2 DB
SATELLITE ANTENNA GAIN	40.6 DB
EQUIVALENT INPUT NOISE PWR DENSITY AT SAT. RCVR	196.6 DB
NOISE BANDWIDTH (0.100 MHZ)	-50.0 DB
UP-LINK CNR	28.8 DB
BACK-OFF OF SATELLITE TRANSPONDER	11.0 DB
CNR FROM INTERMODULATICN IN SATELLITE TWT	18.0 DB
AUDIO DOWN-LINK (2.2 GHZ)	
OUTPUT PWR PER CHANNEL AT SAT. TRANSPONDER	-27.7 DB
SATELLITE ANTENNA GAIN	31.9 DB
PATH LOSS	-190.4 DB
MASTER STATICN ANTENNA GAIN	43.4 DB
EQUIVALENT INPUT NOISE PWR DENSITY AT MASTER STA.RCVR	207.6 DB
NOISE BANDWIDTH	-50.0 DB
DOWN-LINK CNR	14.8 DB
AUDIO TOTAL CNR	13.0 DB
AUDIO TOTAL SNR (=3*(((B/2F)-1)**2)*(C/N)*(B/F)*(1/KP'))	43.5 DB
WHERE KP' IS THE PEAK-TO-AVERAGE POWER RATIO FOR A SINGLE VOICE SIGNAL; OTHER PARAMETERS AS ABOVE	

*** COLOMBIA ***

INPUT PARAMETERS

LAND AREA	439828 SQ MI
LATITUDE OF COUNTRY'S GEOGRAPHICAL CENTER	5.0 DEG
ASSUMED COST OF SATELLITE POWER ($/WATT-YEAR)	$50000.
DISCOUNT FACTOR	10.0%
NO. OF TV-TRANSMIT/AUDIO-RECEIVE (MASTER) STATIONS	18
NO. OF TV-RECEIVE/AUDIO-TRANSMIT (SLAVE) STATIONS	306
NO. OF TV CHANNELS PER MASTER STATION	2
NO. OF TV CHANNELS PER SLAVE STATION	12
SIGNAL-TO-NOISE RATIO REQUIRED FOR TV	43 DB
SIGNAL-TO-NOISE RATIO REQUIRED FOR AUDIO	43 DB

OUTPUT PARAMETERS

MASTER STATION

ANTENNA:	DIAMETER	19.5 FT	UNIT COST	$ 27903.
RCVR PRE-AMP:	NOISE TEMP	90. DEG K	UNIT COST	$ 17000
TXMTR PWR AMP:	OUTPUT PWR	30.0 W	UNIT COST	$ 6000
INITIAL CAPITAL COST PER STATION				$ 56050
PRESENT WORTH OF TEN-YEAR ANNUAL COST STREAM				$ 112794

SLAVE STATION

ANTENNA:	DIAMETER	12.0 FT	UNIT COST	$ 6771.
RCVR PRE-AMP:	NOISE TEMP	180. DEG K	UNIT COST	$ 7000
TXMTR PWR AMP	OUTPUT PWR	1.0 W	UNIT COST	$ 850
INITIAL CAPITAL COST PER STATION				$ 30770
PRESENT WORTH OF TEN-YEAR ANNUAL COST STREAM				$ 47839

SATELLITE

SATELLITE ANTENNA N-S DIAMETER	9.4 FT
SATELLITE ANTENNA E-W DIAMETER	13.3 FT
MAXIMUM SLANT RANGE FOR TRANSMISSION	22419.5 MI
POWER CHARGED PER TV CHANNEL	2.29 W
POWER CHARGED PER AUDIO CHANNEL	0.0410046 W
TOTAL COST PER YEAR OF SATELLITE POWER	$ 1545591
PRESENT WORTH OF TEN-YEAR ANNUAL COST STREAM	$ 949610

TOTAL INITIAL CAPITAL COST (NOT INCLUDING SATELLITE COSTS)	$ 6021167.
PRESENT WORTH OF TOTAL-SYSTEM TEN-YEAR COST	$ 26165440.
ANNUAL COST OF TOTAL SYSTEM PER SLAVE STATION	$ 13852.
ANNUAL COST OF TOTAL SYSTEM PER SLAVE STATION PER TV CHANNEL	$ 1154.

LINK CALCULATIONS

TV UP-LINK (6.0 GHZ)	
OUTPUT PWR PER CHANNEL OF MASTER STATION PWR AMP	13.5 DB
MASTER STATION ANTENNA GAIN	48.8 DB
PATH LOSS	-199.1 DB
SATELLITE ANTENNA GAIN	43.6 DB
EQUIVALENT INPUT NOISE PWR DENSITY AT SAT. RCVR	196.6 DB
NOISE BANDWIDTH (25.1 MHZ)	-74.0 DB
UP-LINK CNR	29.4 DB
TV DOWN-LINK (2.5 GHZ)	
OUTPUT POWER OF SATELLITE TRANSPONDER	3.6 DB
SATELLITE ANTENNA GAIN	33.0 DB
PATH LOSS	-191.6 DB
SLAVE STATION ANTENNA GAIN	37.0 DB
EQUIVALENT INPUT NOISE PWR DENSITY AT SLAVE STATION RCVR	205.0 DB
NOISE BANDWIDTH	-74.0 DB
DOWN-LINK CNR	13.1 DB
TV TOTAL CNR	13.0 DB
TV TOTAL SNR (=6*(((B/2F)-1)**2)*(C/N)*(B/F)*KP)	42.9 DB
WHERE B = RF BANDWIDTH; F = HIGHEST BASEBAND FREQUENCY; C/N = TV TOTAL CNR; KP = A NOISE WEIGHTING FACTOR	
AUDIO UP-LINK (6.0 GHZ)	
OUTPUT POWER PER CHANNEL AT SLAVE STA. PWR. AMP.	-1.0 DB
SLAVE STATION ANTENNA GAIN	44.6 DB
PATH LOSS	-199.2 DB
SATELLITE ANTENNA GAIN	40.6 DB
EQUIVALENT INPUT NOISE PWR DENSITY AT SAT. RCVR	196.6 DB
NOISE BANDWIDTH (0.100 MHZ)	-50.0 DB
UP-LINK CNR	31.7 DB
BACK-OFF OF SATELLITE TRANSPONDER	10.0 DB
CNR FROM INTERMODULATION IN SATELLITE TWT	16.9 DB
AUDIO DOWN-LINK (2.2 GHZ)	
OUTPUT PWR PER CHANNEL AT SAT. TRANSPONDER	-23.9 DB
SATELLITE ANTENNA GAIN	31.9 DB
PATH LOSS	-190.4 DB
MASTER STATION ANTENNA GAIN	40.1 DB
EQUIVALENT INPUT NOISE PWR DENSITY AT MASTER STA.RCVR	207.6 DB
NOISE BANDWIDTH	-50.0 DB
DOWN-LINK CNR	15.4 DB
AUDIO TOTAL CNR	13.0 DB
AUDIO TOTAL SNR (=3*(((F/2F)-1)**2)*(C/N)*(B/F)*(1/KP'))	43.5 DB
WHERE KP' IS THE PEAK-TO-AVERAGE POWER RATIO FOR A SINGLE VOICE SIGNAL; OTHER PARAMETERS AS ABOVE	

IV. Sketch of Progress

Several parts of the final model are presently being constructed. For the terrestrial systems costs needed for comparison with the satellite system costs I have been working closely with Pacific Telephone and Telegraph Co. of San Jose. Two parts of the overall program of six parts have been written. These parts deal with costs for T Carrier equipment on cable-pairs and N Carrier equipment on cable-pairs. Each is appropriate for a different cross-section and total link length. The other parts to the program will deal with microwave radio, open-wire lines, the determination of the least-cost cable-pair size to serve in a given situation, and the coupler program that will take the output from these separate parts and provide answers in the following matrix format. The length, L, of the telecommunications link under study will be given along the abscissa of the output graph. The increase in channel demand per year that must be satisfied by the link, YID, will be given along the ordinate. The matrix element designated by any pair of values (L, YID) will contain the least-cost type of terrestrial telecommunications facility that will satisfy these requirements and the present worth of the facility for the whole period of study.

In considering the time element in a satellite system it is necessary to know the costs of upgrading earth stations. This cost has been difficult to obtain from industry inasmuch as the type of station with which we are dealing (very low cost) is not in widespread use. Nevertheless, some handle on these costs will be obtained from data gathered for the teleconferencing report. The cost will be taken to be

the replacement cost of the component (either antenna, preamplifier, or power amplifier) or components whose upgrading will render the required increase in earth station channel capacity.

A step toward the completion of the integration of educational requirements and telephony requirements into one system has been made with the completion of a version of the original least-cost satellite system program that treats the case where only telephony service is desired. The system is simple in configuration in that each earth station is assumed to have the same G/T and the same power amplifier. Further work will allow perhaps three different sizes of earth station to be determined, according to the demand requirements.

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