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DESIGN FOR AN ELEMENTARY AND SECONDARY EDUCATION COST-EFFECTIVENESS MODEL. VOLUME I, MODEL DESCRIPTION. VOLUME II, THE USER'S GUIDE.

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PUB DATE 30 JUN 67

CONTRACT OEC-1-6-001681-1681
EDRS PRICE MF-$1.00 HC-$9.32 231P.

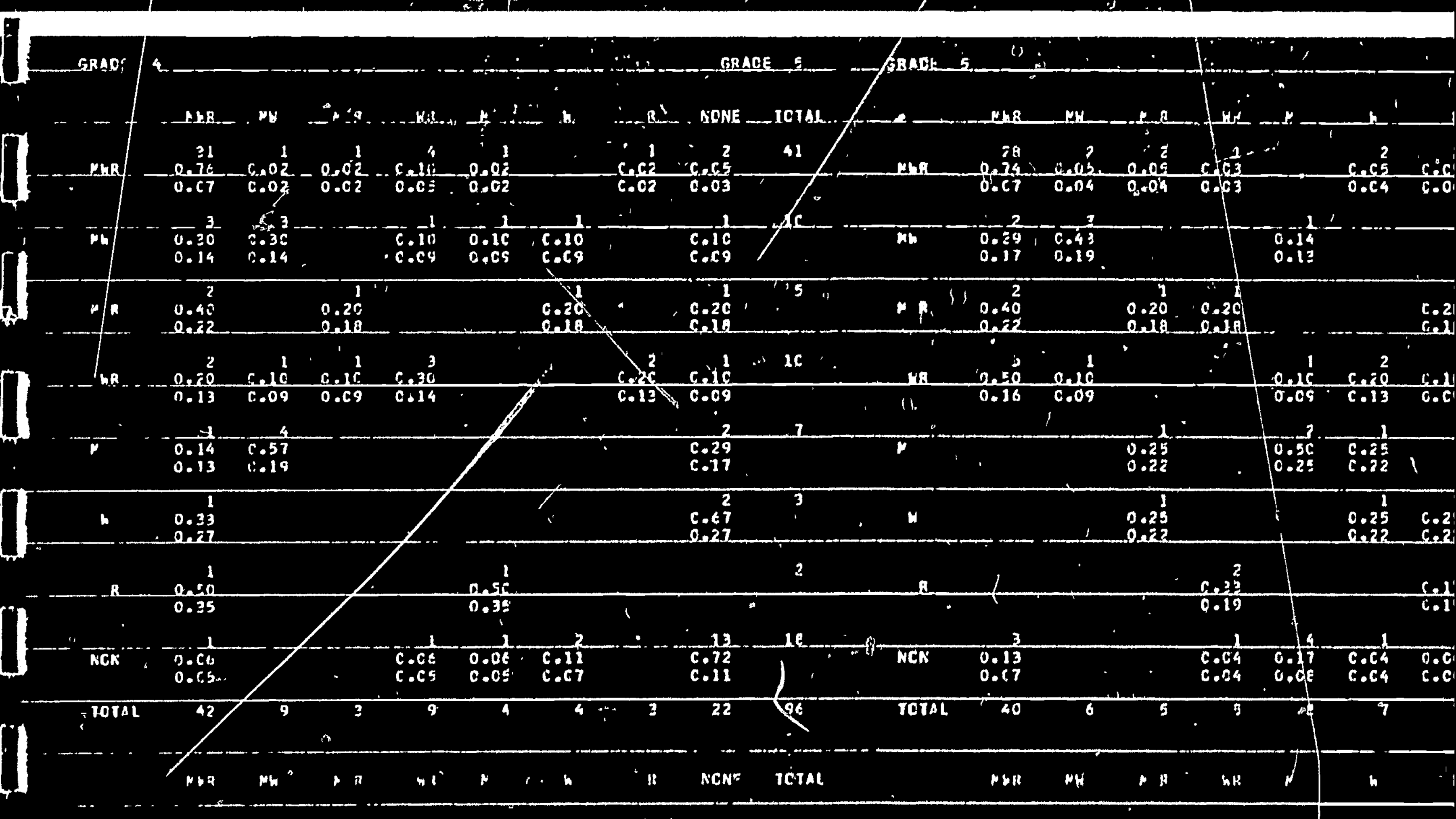
DESCRIPTORS- *EQUAL EDUCATION, *EDUCATIONAL IMPROVEMENT, *ELEMENTARY SCHOOLS, *SECONDARY SCHOOLS, *COST EFFECTIVENESS, SOCIOECONOMIC BACKGROUND, LEARNING PROCESSES, DISADVANTAGED YOUTH, ACADEMIC ACHIEVEMENT, DROPOUT RATE, TRUANCY, CURRICULUM PLANNING, COMMUNITY BENEFITS, RESOURCE ALLOCATIONS, COMPUTER ORIENTED PROGRAMS, EDUCATIONAL PLANNING, FEDERAL LEGISLATION, COMPENSATORY EDUCATION, CAMBRIDGE,

A MODEL INTENDED TO PREDICT THE RELATIVE COST-EFFECTIVENESS OF ALTERNATIVE EDUCATIONAL IMPROVEMENT PROGRAMS WITHIN THE SAME SCHOOL-COMMUNITY SETTING IS DEVELOPED. THE MODEL IS AN ATTEMPT TO AID IN DECISIONS CONCERNING ALTERNATIVE PROGRAMS OF TITLE I OF THE ELEMENTARY AND SECONDARY EDUCATION ACT OF 1965. COSTS ARE ESTIMATED FROM BUDGET ALLOCATIONS. THREE TYPES OF EDUCATIONAL EFFECTIVENESS MEASURES ARE USED--STUDENT GROUP-ORIENTED, SCHOOL-ORIENTED, AND COMMUNITY-ORIENTED. THESE ARE UTILIZED IN TERMS OF SCHOOL AND STUDENT, ACHIEVEMENT CHANGES, AND COMMUNITY, ECONOMIC, AND SOCIAL CHANGES. EACH OF THESE SETS OF PREDICTED CHANGES IS ASSOCIATED WITH THE ESTIMATED COSTS OF THE PARTICULAR PROGRAM CAUSING THOSE CHANGES, SO THAT EACH PROGRAM HAS A SET OF COST-EFFECTIVENESS OUTPUT MEASURES ASSOCIATED WITH IT. THE MODEL USES INFORMATION ABOUT THE CURRENT SCHOOL SYSTEM, THE HISTORIC PERFORMANCES OF SELECTED STUDENT SUBPOPULATIONS, THE SOCIAL AND ACADEMIC CHARACTERISTICS OF THE TARGET POPULATION, AND THE TITLE I PROPOSED CHANGES IN THE SCHOOL ENVIRONMENT. LIKELY SHORT-RANGE CHANGES IN STUDENTS' EDUCATIONAL ACHIEVEMENT AND ATTITUDES ARE THEN COMPUTED AND THE EFFECTS ON LONGER-RANGE CHANGES IN ACADEMIC ACHIEVEMENT, DROPOUT AND TRUANCY RATES, AND COMMUNITY EFFECTS ARE EXTRAPOLATED. THE OVERALL MODEL IS DIVIDED INTO FOUR PARTS--(1) COSTS (INPUTS), (2) INSTRUCTIONAL PROCESS, (3) SCHOOL FLOW, DROPOUT AND TRUANCY CALCULATIONS, COURSE OF STUDY SELECTION, AND COMMUNITY EFFECTS, AND (4) EFFECTIVENESS (OUTPUTS). (HW)

DESIGN FOR AN

ELEMENTARY AND SECONDARY EDUCATION COST-EFFECTIVENESS MODEL

VOLUME I
MODEL DESCRIPTION



FOR THE

U.S. OFFICE OF EDUCATION

(CONTRACT OEC 1-6-001681-1681)

BY

ABT ASSOCIATES INC.
CAMBRIDGE, MASSACHUSETTS

Division of Operations Analysis
National Center for Educational Statistics

Design For An

ELEMENTARY AND SECONDARY EDUCATION COST-EFFECTIVENESS MODEL

Volume I

Model Description

For The

U.S. OFFICE OF EDUCATION

(Contract OEC 1-6-001681-1681)

By

Abt Associates Inc.
Cambridge, Massachusetts

30 June 1967

ACKNOWLEDGMENTS

The development of the Elementary and Secondary Education Cost-Effectiveness Model was supported by the U.S. Office of Education under Contract OEC 1-6-001681-1681. The work was undertaken between 1 June 1966 and 30 June 1967.

We wish to acknowledge with appreciation the support and guidance of several members of the Office of Education: Dr. David S. Stoller, Director of the Division of Operations Analysis, Mr. Murray Spitzer, Chief, Systems Analysis Branch of the Division of Operations Analysis, Mr. James K. Rocks, Director, Office of Plans and Programs, and Mr. Martin Spickler, formerly Education Specialist, Program Development Branch, Division of Compensatory Education. Dr. Richard Powers and Mr. Michael Kirst, both formerly with the Office of Education, were of great assistance.

Dr. Clark C. Abt directed the Conceptual Design phase of the contract and Mr. Peter S. Miller directed the Mathematical Design phase. The following individuals made major contributions to the model design; Dr. Herbert S. Winokur, Dr. Stephen J. Fitzsimmons, Mr. Stephen A. Bornstein, Mr. James C. Hodder, Mr. Grover C. Gregory, and Mr. Louis J. Cutrona. In addition, valuable work was done by: John Blaxall, Julia Cheever, Charles Fisher, Raymond Glazier, Holly Kinley, Emily Leonard, Diane Macunovitch, Sally Merrill, Keith Moore, Martha Mulloy, Michael Pritchett, Robert Rea, Martha Rosen, Richard Rosen, Lorie Vanderschmidt, and Paul Werbos.

The first volume of this report deals with the model design; the second is a tentative description of the operation of the model, subject to revision when computer programming and testing takes place.

The computer output on the cover is taken from research done with data from Greater Boston schools during the project on the validation of the Markov assumptions of the School Flow Submodel. Shown are transition frequencies from grade 4 to 5 and grade 5 to grade 6 relating various combinations of passing and failing in mathematics, reading, and writing.

Design For An

ELEMENTARY AND SECONDARY EDUCATION COST-EFFECTIVENESS MODEL

Volume I - Model Description

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CHAPTER I

SUMMARY OF THE MODEL CONCEPT AND ITS APPLICATION

Millions of dollars are spent every day in the United States to improve the public schools, yet the quantity and quality of education available to many is believed inadequate to meet public demand. Since national human and physical resources potentially useable in the improvement of the schools are competed for by other national needs, only limited resources are available for schools. When improvements are desired and only limited amounts of the necessary resources are available, the efficiency of resource allocation becomes a critical problem.

When there is not enough to do everything desirable, rational resource allocation decisions require information on the relative effectiveness of alternative types of expenditures. The goal is, of course, optimal resource allocation decisions, but optimization much more difficult than evaluation, since it involves the generation of programs, whereas evaluation does not. Optimization is a sensitive and complex problem, but if only evaluation can be carried out, this alone will be useful.

Although millions are spent every day for the improvement of public schools, many more millions than are available would be needed to achieve all of the desired improvements. Thus, some means of estimating the expected returns from alternative types of investments in education is needed, so that the most productive investments may be given priority.

The relative efficiency or rate of return on investment of alternative education improvements may be measured by their relative cost-effectiveness, or effectiveness per cost expended. Both costs and effectiveness theoretically can be measured, but there are many practical difficulties. At least costs can roughly be estimated in advance on the basis of budget allocations. The prediction of effectiveness is much more difficult. Yet without some such prediction, however crude or subjective, there is no rational basis for deciding between one education improvement program and another.

The prediction of education improvement program effectiveness can of course be based on recent experience with similar programs. Such experience, however, is not available for new programs, or programs applied in new settings. Moreover, the effectiveness of previous programs is unfortunately only occasionally measured, recorded and disseminated. The experiences of teachers that are not measured and communicated to education policy makers are of no help in program selection.

The large amount of data stored in every school concerning student achievement levels, student home addresses, and student destinations on leaving school (dropout, graduation, higher education) do suggest that the effectiveness of education improvement programs can be measured in meaningful and concrete terms. If a program's impact on grades, (achievement), on the classes affected and number and quality of graduates and dropouts later on as a result of the program can be estimated, then there is already some measure of effectiveness.

It would be desirable to measure the impact of educational improvement programs on the community as well as the student and the school. Thus both community economic and social effects should be elements in any measure of effectiveness.

If the population is broken down by achievement levels and these are matched with corresponding probabilities of unskilled, semi-skilled, and skilled labor jobs, business and clerical jobs, and professional and managerial prospects, then changes in expected lifetime earnings of students can be estimated on the basis of known averages in each earnings category. Thus the changes in students' prospective income categories as a result of an education improvement program may be estimated. The results also offer some indication of the economic impact on the community of programs for education improvements.

The social change component of any measure of the effectiveness of education improvements is more difficult to measure. because there are so many kinds of social changes, because many are inter-related, and because they are difficult to measure. One major social issue toward which much of the government' investment in education improvement is directed is that of equality of educational opportunity. James Coleman has suggested that equality of educational opportunity is indicated by the absence of correlation between a student's socio-economic background and school achievement. If one can predict who will fail and drop out on the basis of race or family income, for example, then educational opportunity is unequally distributed.

Given this particular measure of social change - absence of correlation between socio-economic background and educational achievement - the social impact of an education improvement program may be measured by classifying the target student population into socio-economic or racial categories, and then determining if the predictability of educational achievement on this basis has declined as a result of the program.

We have now discussed three types of educational effectiveness measures: student group-oriented, school-oriented and community-oriented. The student group-oriented measure is the academic achievement change (grades) resulting from an education improvement program. The school-oriented measures are of three kinds: the consequences of these achievement changes in a given school population in terms of changes in the number dropping out of school, in the number selecting the various available courses of study, and the number and the quality (cumulative achievement level) of those graduating. The community-oriented measures are of two kinds: The average expected lifetime earnings potential of the population (economic change), and the reduced relation between socio-economic level and achievement indicating increased equality of educational opportunity (social change).

The above measures of education improvement are available from school data in retrospect long after a program has been implemented. Unfortunately, such data are not available when the decisions must be made concerning which programs to implement. Hence, some means of predicting these measures of effectiveness of a program is needed before that program is implemented. Prediction always involves a theory about how one thing (the known, or "input") causes another (the predicted, or "output"). If a set of theoretical relationships intended to predict the unknown from the known is to be manipulated for a variety of cases, producing different "outputs" for each different "input" in accordance with some process simulating reality, this set of relationships is often called a model.

The model is a simplified representation, or simulation, of those real world relationships between inputs (assumptions) and outputs (measures of consequences) believed most significant. The model may be expressed as a set of mathematical relationships between inputs and outputs, so that if the input is given the output may be determined. If a model of the educational process is given inputs of specific programs for a specific student population in a specific context, it should produce outputs indicating the changes in educational product. An education system cost-effectiveness model would show the changes in education costs and in measures of effectiveness resulting from changes in the education process from improvement programs.

The education system cost-effectiveness model described in this report is intended to produce the measures of education effectiveness described above, in terms of student and school, achievement changes, and community, economic, and social changes. Each of these sets of predicted changes is associated with the estimated costs of the particular program causing those changes, so that each program has a set of cost-effectiveness output measures associated with it. Given a specific school and community setting, different educational improvement programs may be compared for their relative predicted cost-effectiveness, and the most cost-effective or efficient program may thus be rationally selected.

The input data required by the model to produce these outputs must include quantitative descriptions of the school population to be affected by the improvement program, the improvement program itself, and the school and community settings in which the program and the target population interact. Unfortunately, it is an extremely complex task to describe school and community settings with sufficient quantitative accuracy to predict the results of the same program in different schools and communities, let alone the results of different programs in different schools in different communities. Pending the development of more quantitatively precise theoretical descriptions of how changes in communities interact with changes in schools and student achievements, it seemed wise to limit this first attempt to develop an education cost-effectiveness model to a comparison of alternative programs within the same school and community settings.

In other words, the model described below is intended to predict the relative cost-effectiveness of alternative education improvement programs only within the same school-community setting, and not across communities unless these communities can be assumed equivalent in all respects relevant to the education process.

It is also important to limit initial expectations for the model to measures of the relative effectiveness of alternative programs. So long as the relationships assumed to exist between inputs and outputs have not been empirically tested, corrected, and validated, these relationships are unlikely to produce accurate absolute values of the various measures of education effectiveness. For example, the expected change reduction in numbers of dropouts resulting from two alternative improvement programs might be 40% per thousand dollars for one program and 10% per thousand dollars for the other. This should be taken to mean only that the first program appears significantly more cost-effective than the second, not that it is exactly four times as cost-effective or efficient.

The major problem in the design of any model, and certainly this one, is the determination of the quantitative relationships that translate inputs (assumptions) into outputs (consequences). In the modeling of physical processes, these relationships are usually readily determined from empiracally verified theory, or "laws of nature". In the modeling of technological processes, such as a production line, the quantitative relationships between successive stages from input of raw materials to output of finished goods are also well known, or can readily be determined by observation and measurement. It is in the modeling of social processes involving human interactions that problems arise, because of the incomplete knowledge concerning human decision rules and influence processes. Where these human decisions are numerous and repeated, as in macroeconomic phenomena, statistics on their nature and distribution offer at least probabilistic data on relationships among variables. However, where the process being modeled involves modest numbers of individuals interacting in ways many of which have not yet been quantitatively measured, there are gaps in the linkage between causes and effects that must temporarily be bridged by hypothetical relationships remaining to be corrected or verified by subsequent testing of the model.

In the model of concern here, there is a mixture of quantitative and qualitative knowledge concerning relationships among variables. The cost factors are largeley available in quantified terms. The measures of education effectiveness, however, depend on predictions of how students will respond to a variety of changes in school environment and the quantity and quality of instruction. These behavioral responses are the result of influence processes still only partially understood. The approach that has been taken in this model has been to quantify crudely some of what has been qualitatively and impressionistically described in the literature of education research.

Some of the attitudinal variables believed decisive to the learning process, for example, may be given numerical index ratings roughly corresponding to the qualitative distinctions made in empirical research. The only presently available alternative would have been to omit these troublesome but significant variables, implying a spurious insignificance by such omission. The design preference has been for useful errors of commission rather than useless errors of omission. At least in this way useful areas of further research will be specified.

Note:

The present cost-effectiveness model was intended to aid in decisions concerning alternative Title I programs. Title I is that part of the Elementary and Secondary Education Act of 1965 whose goal is to provide "compensatory education" for the millions of school children deprived by poverty of the cultural environment found to be so important to successful schooling. Over one billion dollars are spent on Title I each year.

The model is equally applicable to many alternative education improvement programs other than those in Title I. The effectiveness of any education improvement program involving changes in school environment, in the quantity or the quality of instruction, equipment, and facilities may be estimated by the techniques used in the present model.

CHAPTER II

QUALITATIVE DESCRIPTION OF THE COMPLETE MODEL

The OECE model has been developed for the purpose of assisting in the evaluation of alternative proposed Title I programs in any particular school district. It does not have the capability of allocating funds across communities, or of selecting the optimum mix of programs and describing a precise menu of expenditures on various programs for a school district or districts. In the hands of a skilled user, it will help to determine the relative effects of any programs the user feeds into the model, and this somewhat limited capability can be a powerful tool for evaluation.

The OECE model is divided into several portions based on the chronological effects of Title I programs on the students undergoing the experience and on the input and output needs of the computer. There are four main portions of the model, and each main portion has from one to four submodels associated with it:

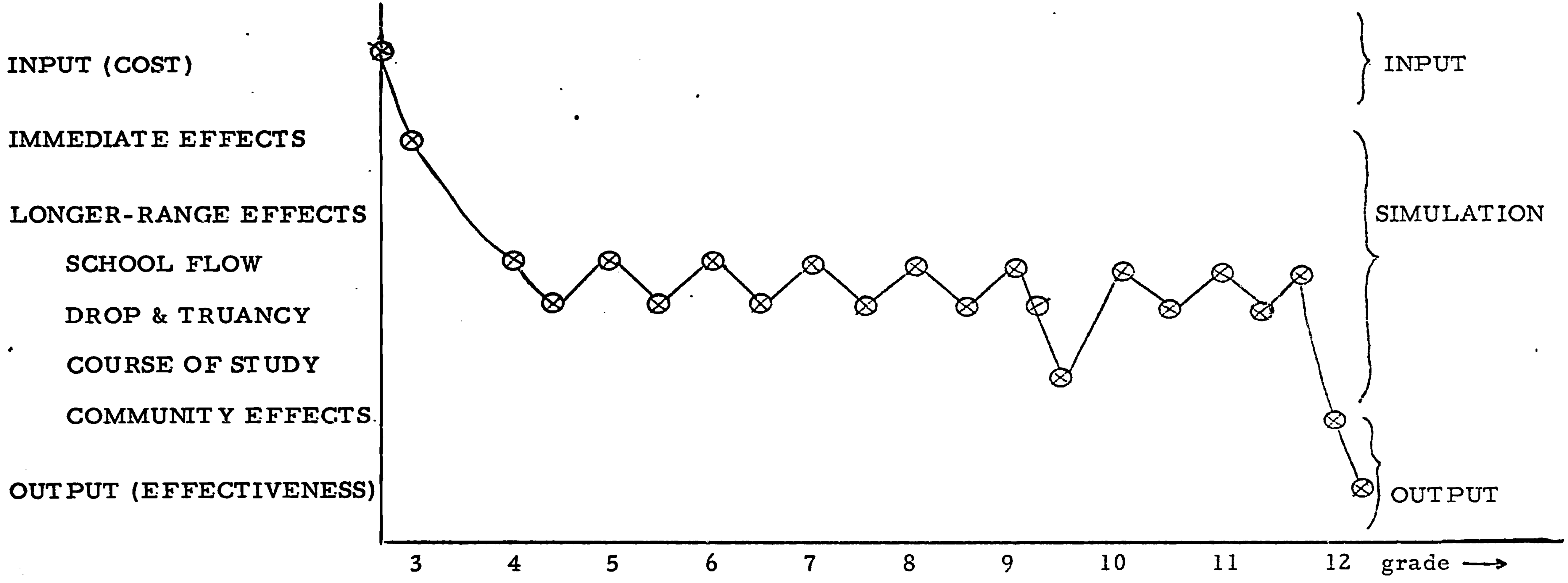
FUNCTION	SUBMODEL
INPUT	COST
IMMEDIATE TITLE I EFFECTS	INSTRUCTIONAL PROCESS
LONGER-RANGE EFFECTS	SCHOOL FLOW
	DROPOUT & TRUANCY CALCULATION
	COURSE OF STUDY SELECTION
	COMMUNITY EFFECTS
OUTPUT	EFFECTIVENESS OUTPUTS

The input part of the model is a straightforward data input and error checking procedure which serves to construct the data-base for the model. It takes as input punched cards with data describing the particular school or school district, the student population, and the community as a whole. After requesting user clarification of ambiguous or incorrect information, the program will make up a data base tape for use with the actual simulation of the effects of the Title I program. It determines whether cost subtotals add up to give the total described on the input cards; in addition, it checks for numbers which seem to be unreasonable. For instance, if the computer program has been told to expect salaries to range between $ 2,000 and $ 18,000, and it is given information describing a school psychiatrist whose salary is $ 45,000 for the school year, it will print out a note indicating the inconsistency, and it will ask for confirmation or correction of this salary by the user.

The third function of the input portion of the model is to check for errors in the punching of data cards. If alphabetic information is detected in a location where numeric data is expected, the program will note it and inform the user.

The immediate effects portion of the model describes the effects of the Title I program in the school during the time it is actually present. That is, if the proposed Title I program is one for remedial reading for fourth graders, the immediate effects portion of the model will calculate and describe the changes which the students undergo in the time period between the end of third grade and the beginning of fifth grade. It is at this point in time--during the ongoing Title I program--that many programs peak in effectiveness, and large changes in student attitude or achievement appear which may or may not damp out later.

The longer-range effects portion of the model describes the progress of students after the Title I program is no longer in effect. In the longer-range section, the results of a program may damp out (in terms of achievement) or they may grow and expand. The former condition seems to occur most often both in the literature and with the model. Changes in



SEQUENCE OF SUBMODEL OPERATIONS

Fig. 1

student achievement over the years, rate of dropout, selection of course of study by the students, and two community-oriented effects are calculated by this portion of the model.

The output portion of the model takes the results of the simulation (both immediate effects and longer-range effects) and prints them out in a report to the user. The manner of organization and presentation of these results has been determined in conjunction with the Office of Education and will be in a format which is familiar to and understandable by educators, educational superintendents, and, in general, non-computer-programmer personnel.

Below are described in somewhat more detail the subroutines which make up the functional elements described above. These subroutines are explained in greater detail, each in its own chapter, later in this volume.

The calculation of the immediate effects of a Title I program (those effects which occur while the program is present in the school) is carried out by the Instructional Process (IP) Submodel. This submodel determines the change in student achievement level which takes place during each year that the Title I program is in effect. The IP calculates the extra achievement gain over that which would ordinarily occur in the absence of a Title I program, and gives as a final output, the total change in achievement for the appropriate year(s).

The achievement change caused by Title I is computed on the basis of two factors: the change in the overall effectiveness of the classroom environment, and the change in an overall student attitudinal variable which describes the students' resistance to learning based on their sociological backgrounds. As the effectiveness of the curriculum of the school increases, achievement will increase, as it will if the student impedance to learning variable decreases.

The curriculum elements of Title I programs affect the classroom or curriculum portion of the Instructional Process submodel, and service elements affect the impedance portion.

The overall curriculum variable reflects the values of indicators which describe the quality of instruction and the quantity and intensity of instruction. By ascertaining changes (before and after Title I) in these indicators, the IP can determine the change in this variable.

The student impedance variable is somewhat more controversial. Indicators of disadvantage are measured for the average child to determine the amount or level of impedance characterizing him before the introduction of Title I programs. The potential programs are then analyzed in terms of their relevance to these factors of disadvantage. That is, is there a service provided by the program which will tend to make up for the background disadvantage of the student? If so, then student impedance will decline, and achievement will improve. If there is no service offered by the proposed program, or the service provided is on the whole irrelevant to the needs of the child, then any change in achievement will have to come about through the curriculum half of the Instructional Process submodel.

For example, a program which provides free lunches for children who have a history of low family income is deemed relevant since it tends to offset one of the disadvantages of these children. On the other hand, a program to provide eyeglasses for children who already see well on the average will not be relevant to any of their factors of disadvantage and will not decrease their impedance toward learning. From the literature, it seems that many of the programs which are attempted and which are unsuccessful do not approach this important area of non-schoool-based student characteristics.

Summarizing, the Instructional Process submodel predicts a change in achievement through the use of these variables, calculating change up to the point where the Title I program no longer is being operated for the particular target group in question. At this point, the longer-range effects portion of the model takes over. The first submodel in this part of the model is the School Flow submodel, which traces the achievement patterns of the students through the rest of their scholastic career up to the point where they either drop out or graduate from high school. The School Flow submodel indicates the pattern of achievement for a group of students in any grade based on two factors: the achievement pattern for the group in the grade immediately preceeding the grade in question, and a set of transition probabilities describing the likelihood of a student's moving from a particular pattern in the one grade to a particular pattern in the next. For instance, one of the probabilities might be described by saying, "If a student in this particular community or type of community passed English and math in grade 4 but failed science and social studies, the chance that he will pass English, math, and social studies but fail science in grade 5 is .03."

If there is a Title I program in the third grade, the Instructional Process submodel will describe the achievement change for students in the third grade. Starting with the fourth grade, the School Flow model will extrapolate, from year to year, the achievement change for this group of students, keeping track of the whole group until its members either graduate or drop out.

The Dropout/Truancy submodel is also in that part of the model which calculates the long-range effects of projected Title I programs. At the end of each school year this submodel determines the number of dropouts and the average truancy rate for the preceeding year. The truancy rate is recorded for output purposes, and the dropouts are removed from the group of students whose achievement average is to be extrapolated through the following years. The point at which students drop out is recorded and used both as an output and as data for the calculation of potential lifetime earnings.

Dropouts and truancy rates are determined by means of a relatively simple mathematical model, due to the limited availability of data describing their underlying causal factors. This complex problem could not be considered in as much detail as would have been desirable in a research model due to these data problems. The model developed here is a linear one, which multiplies the change in average achievement and in the impedance variable described earlier for students by factors reflecting the relative importance of these two variables in changing dropout rate in the particular school. The model will be programmed so as to be adaptive, that is, given data on actual changes caused by Title I projects, it will attempt to adjust itself to best possible values for these parameters.

Another part of the long-range effects portion of the OECE model is the Course of Study Selection Submodel. This part of the model allows for the choice (in those schools which offer a choice of courses of study to students) of a particular course of study such as, college preparation, vocational education, commercial/business, and so on. The results of this submodel are used both as output to the evaluators and as input data to the part of the model which determines the potential earnings of students.

The procedure by which this submodel determines the change from historical patterns of course of study selection by the students as a result of Title I programs is covered in detail by Chapter VIII. In summary, the model receives changes in the mean values of achievement for students at the point in their school careers at which they select a course of study to follow. Based on the upward (or perhaps downward) shift in distribution of achievement for the students, the model makes more students eligible for those courses of study for which a higher achievement mean is required. The course of study selected by the students as a result of the change in their achievement means will depend upon their backgrounds and the kinds of factors described in the Instructional Process Submodel.

The outputs of the preceeding submodels are presented to the user for analysis, but they are also needed as data for the Community Effects Submodel. There are two kinds of outputs to be derived from this submodel. The first kind of output deals with the expected or potential lifetime earnings of the students, and the change in these figures as a result of the proposed Title I programs. The potential lifetime earnings figures are calculated on the basis of three important variables: 1) whether he drops out of school or not, and if he does, when he does; 2) the course of study he has selected in school, if the point of specialization has been reached; and 3) for graduates, their achievement levels upon graduation. The second kind of Community Effects output is an indicator which describes Coleman's concept, "the equality of educational

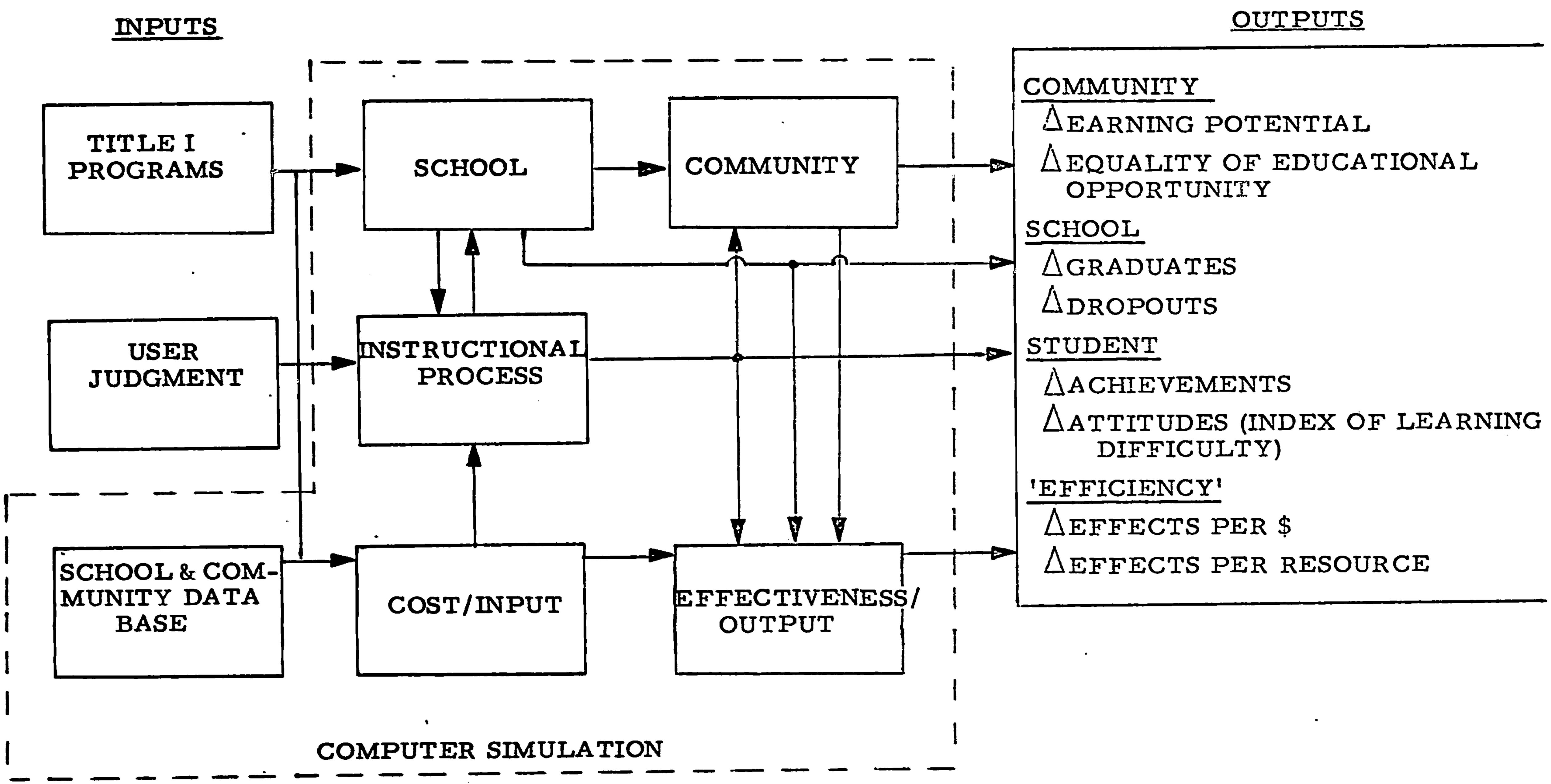


Figure 2: Cost-Effectiveness Model Overview Showing Inputs, 5 Submodels, and Outputs.

opportunity." That is, the association of student performance with student background is measured. To the degree that such an association is not present, to that degree there is said to be equality of educational opportunity.

The last portion of the overall model is that part which will provide output for study and analysis by the decision-makers involved in evaluation. The purpose of the model design is the development of a tool to aid decision-making, and to achieve this goal, the output from the model must be in a form which its users can understand and work with. The output shows the effects of a particular program, by itself, so that the general educational areas in which the program will have impact can be seen, and so that it can be determined whether the program will have beneficial or deleterious effects on the students in the school in question. More important, however, is the function of the program of evaluating alternative proposed projects in a particular school or school district so that they may be readily compared by Title I decision-makers.

Following the next chapter, more detail may be found describing the subroutines of the model.

CHAPTER III

QUALITATIVE ASPECTS OF THE MODEL DESIGN PROCESS

The development of a model for evaluation of proposed Title I projects requires a through understanding of how and to what extent the various aspects of the overall student environment affect student attitudes and achievement. Complete understanding does not exist, and it is rarely possible to predict precisely what will happen to a group of students when certain changes are made in their school environment. On the other hand, it is not impossible to try to isolate those aspects of the environment which appear to have the most influence on student performance. Using the results of educational theory and experiment, the isolated variables can be related to one another in such a way as to simulate the actual educative process.

The Office of Education Cost-Effectiveness (OECE) model is a first attempt at simulating the real world process of education in a general framework. It was designed in response to the need for evaluating the relative effectiveness of alternative Title I project proposals for compensatory education. Its principal function is to provide a more systematic and unbiased assessment procedure than either educated guesswork or straightforward historical comparison now provide.

A model of an incompletely understood process is necessarily partly a simplification and a distortion. It will not be exhaustive or accurate because it does not comprehend every influence in the simulated process and because the relationships between even those influences that are known are not precisely understood. The OECE model is no exception to this rule. Its designers were faced with the problem of determining which of the known elements of compensatory education were of primary interest and which were not,in symbolically representing the process. The choices were conditioned by the ultimate purpose of the model and by the availability of supportive theory and required data.

Underlying the model are important hypotheses. These hypotheses are derived from qualitative learning theory, some quantitative research results of Dave, Bloom, and Coleman, and assumptions made by the design staff at Abt Associates, Inc., and their consultants.

Instruction is the principal production subprocess of education. The teacher, the curriculum materials, and the class itself represent the potential amount of learning that could be gained by any student in the room given satisfactory ability on the part of the student. The student may resist instruction. Were he to be completely responsive to his environment, the student would absorb that which could be learned in the classroom to the level of his ability. In effect, his resistance would be zero and the instruction transmitted to him would be completely converted into learning.

The difference between what is taught and what is learned (ability aside) is the amount of resistance the student has to his environment. When a large number of children in a school are under-achievers, this achievement gap may probably be attributed almost entirely to resistance, not ability constraints. Whatever his reason--laziness, fatigue, dislike of the teacher, boredom, anxiety, or even lack of nourishment and proper clothing--a student reduces the efficiency of teaching by his negative disposition.

If grading in a given classroom is fair, then teaching efficency is the difference between what the teacher teaches and what the student learns, and will show up in the level of student achievement. That is to say, student achievement can be described in terms of the amount of potential instruction available and the amount of resistance the student poses against that instruction. The relationship between these three variablescan be expressed mathematically by calling achievement level the quotient of the amount of potential instruction divided by the student's resistance to learning.

This realtionship implies that achievement increases as the amount of potential instruction increases if the student's resistance either remains constant or decreases. It also suggests that if the amount of potential instruction were to remain constant and the resistance of the student were decreased, achievement would also rise. An analogy can be drawn between this simple relationship and Ohm's Law in electrical theory. Instruction flows from teachers to students, whose resistance lowers the resultant achievement force.

How interdependent instruction and student resistance are poses an interesting problem. Can there be any achievement if resistance is abnormally high or instruction abnormally low? Common sense suggests that the two factors are conditional upon one another, that is, for certain ranges of each the other is operative. An experienced teacher of youngsters from culturally-deprived homes will no doubt support the contention that little learning takes place when students are negatively disposed toward schoolwork and receive no reinforcement outside the classroom. On the other hand, students from very privileged backgrounds are intolerant of low-level teaching and, presumably, increase their resistance as the quality of instruction decreases.

This basic conceptual relationship between the level of instruction, the resistance of the student to learning, and student achievement can be translated into a model of compensatory education. First of all, by its very definition, compensatory education would seem to be addressed to students with resistances greater than zero. These students are underachieving because they are not learning all they are taught. Changes in the amount of instruction (within the proper range or resistance) will yield gains in student achievement. Changes in resistance will similarly increase achievement if the instructional level is adequate.

Changes in the amount of instruction can be brought about by Title I projects aimed at improving the quality of teaching or the qualtity of the curriculum. Changes in resistance cannot be brought about directly by Title I. However, these changes in a student's disposition toward learning do take place as an indirect result of Title I service projects. The aim of service projects is to reduce the ill effects of improper health and welfare attention in the students' home environments. By so doing, service projects tend to increase students' receptivity to learning or, to put it another way, reduce their resistance to formal instruction.

The next step in defining the model is to identify those aspects of instruction, service, and student resistance which contribute most heavily to determining actual achievement and attitude change. Davy, Bloom, Coleman, Bernstein, and other social psychologists have made significant advances in identifying the characteristics of a student's environment which account for the large part of his achievement change. Unfortunately, the variables they have suggested in their research are not usually objectively measurable or easily accessible. The student's sense of mastery over his environment, his need-achievement, his parents' valuing of education, the norms of his peer group, the verbal facility of his teacher, and even the language patterns of his parents are identified as crucial influences on student achievement. Attitudes toward school appear to be less determinate than achievement and dependent upon even more inaccessible variables.

To replace the important influences identified in the literature of educational research, indicators--reliable and accessible--had to be found which suggested the most salient aspects of the crucial variables. The parents' level of education, for example, was selected as an indicator of the value placed by the parents on education. Other indices, like the recency of curriculum materials as an indicator of their interest and relevance to the students, were far less proximate because of the limitations on the standardization and collection of objective data.

These indices, representing the significant influences of the home and school environments on student attitude and achievement change, were then grouped into the four categories: achievement change, instruction, service, and student resistance to instruction. Each category received an overall index equal to a weighted linear combination of each of its variable components. The weights represent the influence attributed to each variable in its respective category.

The basic relationships among the categories are operated by introducing a detailed description of a Title I project into the model. One cycle of the model will yield the attitude and achievement effects of a given project at the time of impact. This information is then passed on to several other subroutines which extrapolate the forecast data out to grade twelve and into the community. The School Flow Submodel receives the information and computes the effect of an achievement change in one achievement category in the year of impact for all achievement categories through grade twelve. This model is based on the subject interdependencies of the core curriculum and computes changes in the probabilities of failure in all subjects and in all higher grades as a function of a change in one subject in any one grade. Changes in truancy rate, expected number of graduates and drop-out rate, and course of study selection are computed with the same attitude and achievement change information. Finally, the impact on the community is estimated along two dimensions, the increase in the expected average life earnings of the target population and the equality of educational opportunity in the community.

Any given Title I project will have costs associated with its components of environmental change. When the effects are tabulated for these changes, the individual project effects and costs are measures of the relative cost-effectiveness of the project.

The first step in the design of any model is the definition of outputs to serve the model's objectives. The outputs of the process of compensatory education are defined as changes in student attitudes and achievement. Presumably, these changes will vary in accordance with the differential emphases of various Title I projects and the amount of effort expended. For purposes of evaluation, however, the effects of Title I projects have to be combined with their costs in order to arrive at a measure of relative effectiveness. Two competing projects, for example, may yield equivalent achievement gains for the target population with widely different costs. The cheaper of the two projects would be the more cost-effective. Two other projects may yield equivalent achievement gains in incommensurate categories, such as reading and arithmetic, at the same cost. In this case, cost-effectiveness is identical for the two projects, unless either reading or arithmetic is considered more beneficial to the students affected by the project.

Following the designation of outputs is the selection of instrumental variables and data inputs. The instrumental variables in the compensatory education process are those influences in the school which contribute most to student attitude and achievement change and which can be affected by projects under Title I. Since Title I is divided into two categories, personal services and instruction, these same categories were used in classifying school environment variables. The logic employed in the classification was straightforward. Both categories were divided into measures of their quality and quantity. The combination of these two measures represents the total impact service and instruction have on the ultimate changes in student attitudes and achievement.

Data inputs consisted of a detailed description of the proposed Title I project and a characterization of the target population. The Title I project was described in terms of its costs and the changes it purported to make in the quality and quantity of services and instruction provided by the school. The components of Title I changes are described in terms similar to those of the instrumental variables so that the model does not go through an unnecessary process conversion.

Students in the model are characterized in two complementary ways. The first description is an ethnic/income breakdown. The model deals with four so-called student-types: whites whose parents' income exceeds $2,000, non-whites whose parents' income exceeds $2,000, whites whose parents' income is less than $2,000, and non-whites whose parents' income is less than $2,000. This breakdown exists so that possible differences in student background and resulting impedance to learning may be rated. The second dimension is so-called student impedance. Impedance represents the degree of scholastic disadvantage that characterizes each student type. It is a combination of home and school background factors which are presumed to retard learning in the target groups.

In a model, input variables are combined with instrumental variables which interact with one another to product the outputs. The combinations and interactions of the model variables require a set of decision rules and precise designations of the relationships among the variables. These rules and relationships constitute the theory of the model.

The theory of the OECE model is relatively simple. It consists of two basic relationships and a number of assumptions. The first relationship is that the decrease in student impedance is proportional to the total increase in the quality and quantity of personal services provided by the school. This relationship assumes that improved services in the school will tend to reduce the scholastic disadvantages accumulated by the target students in their homes and in previous school years. The change in scholastic disadvantage forecast by the model is taken to be equivalent to the change in student attitudes and is output as such.

The second relationship is that the change in student achievement is directly proportional to the total change in the quality and quantity of instruction and inversely proportional to the total change in impedance. This implies that achievement change can be accomplished by holding impedance constant and increasing instruction, by holding instruction constant and decreasing impedance at the same time.

Certain rules, however, govern the behavior of these relationships. Service components of Title I projects are matched against the particular disadvantages of the target population before any impedance change is computed. If the service improvements are not relevant to the student disadvantages, then no impedance change is recorded. A second constraint on the behaviors of the variable relations is the imposition of thresholds. One example of the operation of this constraint occurs also in the computation of impedance change. Because impedance actually represented student attitudes, there was much evidence to suggest that there was a practical limit on the amount of change that could occur in a single year irrespective of the amount of service improvement in the school. Thus an upper limit was placed on the impedance change relationship for any given year.

These two relationships indicate what immediate impact a Title I project will have on student attitude and achievement. Evaluators interested in the longer-range effects of a given project can turn to the following four features of the model: the effect of a change in achievement in the year of impact on achievement in future years all the way to grade twelve (School

Flow Submodel); the effect of changes in achievement and impedance in the year of impact on student absence (Truancy Subroutine) and drop-out proneness (Drop-out Subroutine) to grade twelve; the effect of changes in achievement and impedance in the year of impact on student selection of a course of study (Course of Study Selection Subroutine) and expected lifetime earnings (Community Effects Submodel); and, finally, the effect of changes in achievement in the year of impact on the equality of educational opportunity (Community Effects Submodel).

The School Flow Submodel has been developed with the basic assumption that early failures in academic subjects lead to later failures in other subjects. This effect is likely to spread in later years of school, due to the increasing reliance of new subjects on those previously taught. For instance, reading ability is necessary for most subjects from early elementary school on, mathematical skills are necessary for a wide variety of subjects later on in school; science and social studies courses often build on previous courses. Detailed study of achievement data collected by Abt Associates staff members both in the greater Boston area and in Iowa revealed that patterns of spreading achievement failure do indeed exist both for achievement test data and for teacher-assigned grades.

The subject-grade interdependencies are simulated in the model by the use of a one-stage Markov model; probabilities of passing a set of course in one grade are determined by the pattern of courses passed by the student in the previous grade. Tests of the Markov property of some of the data gathered have been encouraging and are described in more detail in the Notes at the end of Chapter VI.

Drop-out and truancy phenomena were studied in some detail by Abt Associates staff members and a relatively complex model was developed (described in the September and February interim reports). Unfortunately, due to two factors, the model had to be simplified. These factors were: (1) the absence of data on many of the variables which were felt to be important, and (2) the insensitivity of many of the variables to changes attributable to Title I programs. The original model dealt with such influences as the home environment, peer group pressures, community income distribution, employment rates, and family size and crowding. In its simplified version, the model consists of a simple linear relationship of changes in the dropout and truancy rates to changes in achievement and attitude. This simplification is assumed valid for small changes in the rates.

The Course of Study Selection Submodel is a straightforward mathematical development of the assumption that for students of a given background, selection of courses of study is a function of student achievement; the patterns of student choice are based on historical achievement data, and shifts in achievement will result in shifts in choice of course of study.

The Potential Lifetime Earnings portion of the Community Effects Submodel is based upon research into studies of the association of lifetime earnings with educational level achieved, and census report data. As grade of school-leaving increases, as achievement at graduation increases (generally), and depending upon occupation chosen (and before that, course of study selected), lifetime earnings increase.

The Index of the Equality of Educational Opportunity is based on Coleman's concept of the relationship between school achievement and socio-economic background and is described in detail in Chapter IX.

A Cost Subroutine outputs to the user of the model the total costs of the individual projects. When these costs are weighed against the immediate and long-range effects of projects, the relative cost-effectiveness of any one project in a set can be computed. Incommensurate effects that are equally cost-effective can be resolved by assigning priority values or benefits to the individual categories of effects.

The OECE model was developed for the purpose of assisting in the evaluation of alternative proposed Title I programs in any particular school district. It does not have the capability of allocating funds across communites, or of selecting the optimum mix of programs and describing a precise menu of expenditures on various programs for a school district or districts. In the hands of a skilled user, it will help to determine the relative effects of any programs the user feeds into the model, and this somewhat limited capability can be a powerful tool for evaluation. To build a model which could generate and optimize programs for a group of school districts would require a great deal of additional resources and effort.

The development of the model was influenced by the requirement that the model be able to deal with a wide variety of school districts throughout the United States. These different districts have records and data which vary widely in quality and pilosophy. Unfortunately, it is necessary in such a situation to design the model to accept as input data which are much nearer the worst available than the best available. This data constraint is another reason for using commonly available indicators in the model rather than more interesting variables, sociologically correct or theoretically valid, but unavailable.

The outputs will be in a form which will help the users to perform the selection task. Not only must the information for making these evaluations be present, but it must be in a form which will be comfortable for the user to deal with; and it should be so presented that if the user has intuitive disagreements with the model on certain aspects of its indication of student progress, these conflicts will be brought into the open immediately. This feature will be particularly important in the early days of the use of the model, for it is as this point in time that the parameter settings will be based on the least data and that operational experience and familiarity with the dynamics of the computer model will be at a minimum.

The features of functionality, ease of use, and understandibility have been built into the model and its outputs as much as possible. In the future, it will possibily be necessary to redesign portions of the output (and the model) as experience is gained. The direction of this revision, if any, cannot be foretold; if it had been known, it would have been designed into the model so that redesign would be unnecessary. The design of the model and of the outputs has been coordinated with the Office of Education; this coordination should keep the adjustments to a minimum.

The last page of this chapter describes the functions and uses of the Office of Education Cost-Effectiveness Model.

A Brief Profile of the OECE Model

The Model Will:	Function	The Model Won't:
Deal with groups of students Deal with students below national norms Indicate changes in student group achievement	Students and student change	Deal with individuals Evaluate programs to raise achievement of students above national norms
Indicate changes in rate and year of dropouts Indicate increased or decreased numbers of high school graduates Indicate changes in course of study selection where applicable	School change	Simulate changes in the administrative policy in a school district
Indicate changes in potential life-time earnings Indicate changes in equality of educational opportunity	Community change	Simulate change in the home as a result of Title I
Compare the cost-effectiveness of proposed Title I and other educational improvement projects within a school district Aid decision-makers Determine relative effectiveness of proposed Title I programs	Evaluation	Compare proposed Title I projects across districts Make decisions Determine absolute effectiveness of proposed Title I programs
Need commonly available data	Data input	Give results more precise than the input data

CHAPTER IV

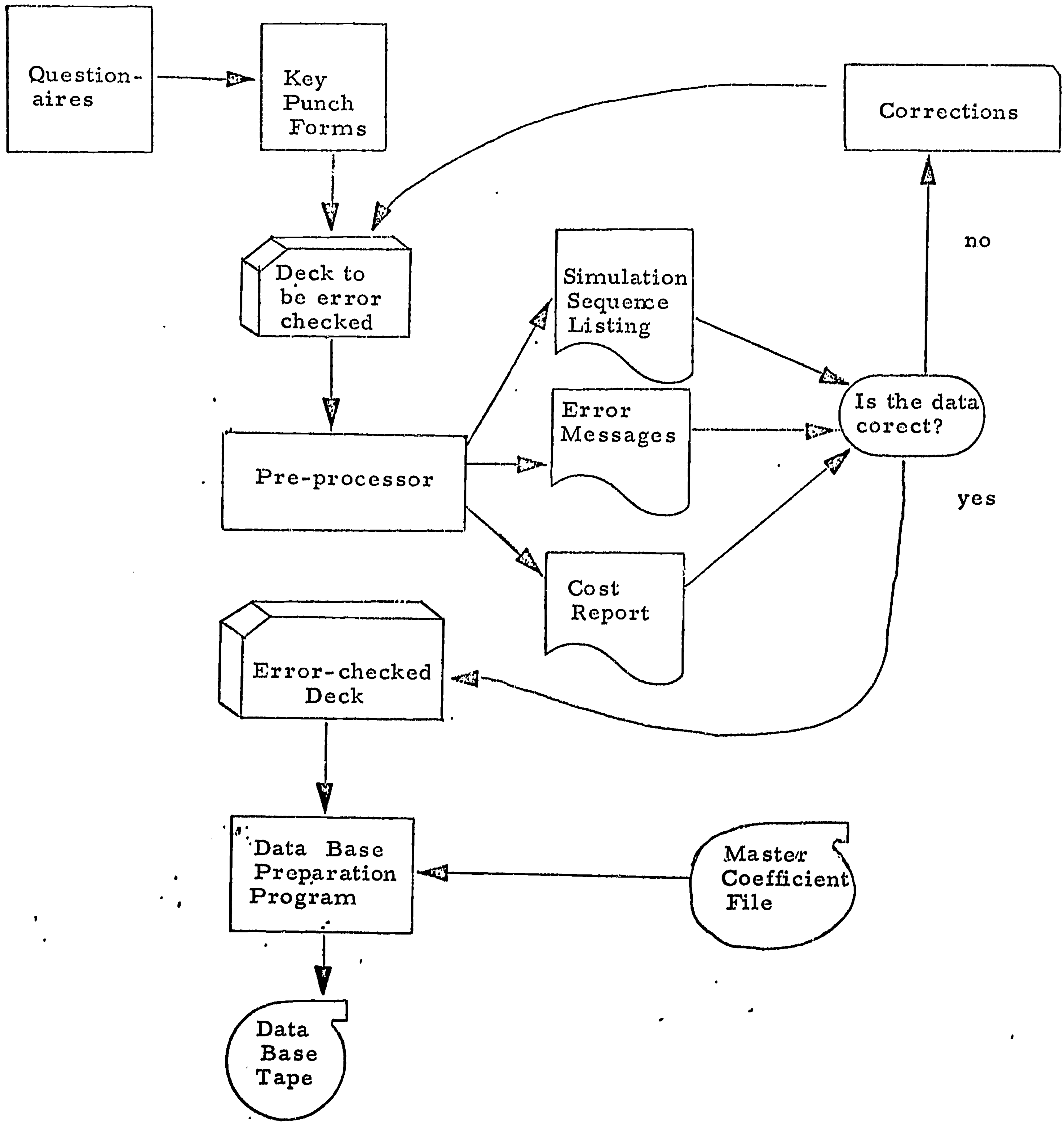
THE COST/INPUT SUBMODEL

The Cost/Input Submodel converts the data concerning a school system and its proposed Title I projects into a form acceptable to the main model, checks the data for certain detectable errors, and generates reports that facilitate the comparative evaluations of proposed projects and the correction and verification of the data about those projects.

The processor consists of two elements: the pre-processor and the data base preparation program. The first of these elements checks errors and generates reports. The second element arranges the data into the sequence required by the main model's logic. These two elements are operationally independent of each other. The pre-processor is the first element to receive the data for a particular school system. It examines them for errors in completeness or consistency and produces, if necessary, the appropriate error indications. In addition to the messages, it generates listings useful for cross project cost comparisons and a listing for verifying the schedule of target group-project combinations to be simulated. These various reports go to whoever is running the model and indicate whether the data should be corrected and resubmitted to the pre-processor or left as they are and submitted directly to the data base preparation element.

The second element takes the presumably error-free data and combines it with various data that are independent of the particular school systems or projects being evaluated to produce a data base on an input tape for the main model. Figure 1 shows the overall process.

Before examining the operation of these elements in more detail, some consideration should be given to how the nature of the model's data needs have shaped the processor. As noted in Chapter V, the "target group" concept is central to the simulation's structure. A simplified description of the model is a device that predicts the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corect?
Pre-processor
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Cost
Report
Error-checked
Deck
Data Base
Preparation
Program
Master
Coefficient
File
Data
Base
Tape

Figure 1

relative changes in the performances of target group members on the basis of expected increases or decreases in measures of selected factors of the school environment of the target group. Necessarily, then, data about proposed projects must be oriented about the target group concept to be useful to the simulation. In general, however, the data currently gathered for the evaluations of proposed Title I projects are not oriented about target groups as they are defined for the OECE model. And, indeed, those responsible for planning projects at the local level may very well structure their programs so as to include student sub-populations that differ considerably from the particular target group configurations assumed here. A result of these differing approaches is that a project seen as an entity by its local planners is seen by the model as a set of projects affecting a number of different target groups differentially.

When this situation exists, and if the model is to assist in the evaluation of this set, the local administrator must supply data disaggregated to and oriented about this target group project level. Unfortunately this disagregation cannot always be done meaningfully by simply prorating the aggregated values on a populatio basis. Instead--as may be seen from an examination of the questionnaire--the administrator must supply somewhat detailed breakdowns of the data by target group and subject areas.

The first and most obvious result of these target group considerations is the form assumed by the cost reports generated by the pre-processor. Rather than being concerned with an entire local project, they focus on the costs for a target group and the costs per target group member. These costs are broken down in a number of standard categories (see OE Form 4305, Items 8a and 8b) and into the specific factors which are actually incorporated into the model. An example of a cost report is shown in Figures 2A and 2B.

Besides generating this cost report, the pre-processor attempts to ensure that the input data is valid. This data is of three different types; two of these types may be inferred from the discussion above, specifically, data must be included that is descriptive of the sub-

COST REPORT

PROJECT NAME: Intensive Teaching
PROJECT ID NO.: 4

Ferndale, Massachusetts

Target Population ID No. 1020 Grade: 3

Distribution by Student Type

White More Than $2000 Family Income	105
White Less Than $2000 Family Income	85
Non-White More Than $2000 Family Income	110
Non-White Less Than $2000 Family Income	400
Total Population	

Project Budget for Target Group 1020

	Cost For Entire Target Group	Computed Cost Per Group Member
Administration	0	0
Instruction	8000	200
Attendance Services	0	0
Health Services	0	0
Pupil Transportation Services	0	0
Operation of Plant	0	0
Maintenance of Plant	0	0
Fixed Chargers	0	0
Food Services	0	0
Student Body Activities	0	0
Community Services	0	0
Remodeling (Less than $2000)	0	0
Equipment	0	0
Professional Services for Sites	0	0
Sites and Site Additions	0	0
Improvements to Sites	0	0
Professional Services for Building	0	0
Remodeling ($2000 or more)	0	0
Equipment (obtained as part of construction)	0	0
Input Total	8000	200
Computed Total	8000	200

Figure 2A

COST REPORT

PROJECT NAME: Intensive Teaching
PROJECT ID NO.: 4

Ferndale,
Massachusetts

The following increases (or decreases) are expected for target group 1020.

Service Factors	
Change in Number of Service Professionals	0
Change in Service Exposure Time	
Hours/Day	0
Days/Week	0
Weeks/Year	0
Cost of Service Supplies and Equipment	0
Instruction Factors	
Change in Number of Teachers	2
Change in Salary Per Teacher	0
Change in Student Exposure Time	
Hours/Day	0
Days/Week	0
Weeks/Year	0
Cost of Instructional Supplies	0
Change in Number of Desks	0
Change in Number of Texts	0
Change in Text Copyright Date	0

Figure 2B

projects and of the target groups. In addition, data must be included about some aspects of the entire school system for which the proposed project is being evaluated. For each type of data set there is a group of tests in the pre-processor which examines the relationships among the data within that particular set. Another group of tests is responsible for examining the relationships between data sets. Figure 3 indicates the overall way in which these groups of tests and the cost report generation are related to each other in the pre-processor. Some of the details of these tests are described below.

Parts of the school system, proposed project, and target group data sets are checked in a similar manner. Answers to certain sections of the questionnaire provide data at the individual item, "subtotal," and "total" levels of aggregation (c. f. sections A. 1, A. 2, A. 3, B. 6, C. 4, & C.5 of the questionnaire, Volume II, Chapter III). Independent computation by the pre-processor of the totals using the given item and subtotal information provides a simple and effective test of the arithmetic correctness of these data. Detection of disagreements among these data causes printing of the appropriate message from Table. 1.

The data describing the proposed projects are checked to see if the project's budgeted costs (such as those indicated in Section B. 6 of the questionnaire) imply the proposed changes in the school environment (such as those indicated in Sections B. 4 to B. 5) and _vice versa_. Table 2 indicates the tests for these implications and the messages generated if there are seemingly false implications.

Besides the above intra-set tests, there are tests which check inter-set relationships. For any one school system there are likely to be several different combinations of target groups and proposed projects. For example, a school system may wish to evaluate the cases where Project X is applied in the 3rd grade, where Project X is applied in the 5th grade, where Project Y is applied in the 3d and 4th grades simultaneously, and where Project Z is applied in the 5th grade. If simulations are to run correctly, it is necessary that the characteristics of the affected 3d, 4th, and 5th grade students

THE COST/INPUT SUBMODEL'S PRE-PROCESSOR ELEMENT

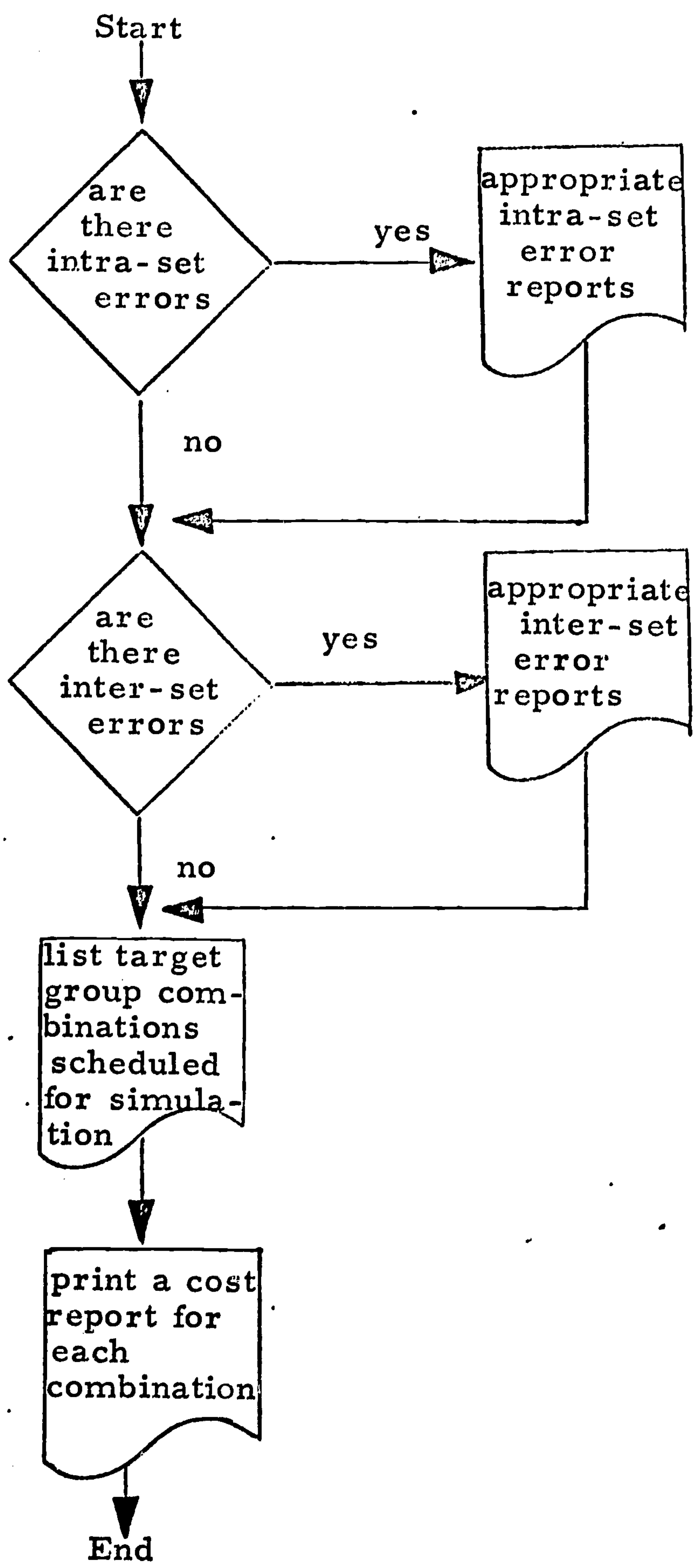


Figure 3

TABLE 1

INTRA-DATA-SET ERROR MESSAGES

Data about the student population in section A. 1 for grade i are inconsistent

Data about the number of truants in section A. 2 for grade i are inconsistent

Data about the number of dropouts in section A. 3 for grade i are inconsistent

The student population in the grade levels which have courses of study as indicated by section A. 5 does not agree with the population as indicated in section A. 1. An error is indicated in either A. 5 or A. 1 or A. 4

Row j in section C. 4 or C. 5 is inconsistent

The itemized and total costs in section B. 6 are not inconsistent

TABLE II

PROJECT COST CONSISTENCY REPORT MESSAGES

1. There is an increase in administrative costs with no increases in any other areas.

2. Student hours increase with no increase in operation budget.

3. The square footage per child increases with neither an increase in construction budget nor a decrease in population.

4. There is a budget for construction; with population steady or declining square footage per child does not increase.

5. There is a budget for professional sites services with no budget for other site related activities.

6. There is a budget for site acquisition or improvement with no budget for site services.

7. There is a budget for professional building services with no budget for building or major remodeling.

8. There is a budget for building or major remodeling with no budget for progessional building services.

9. Texts are updated with no entry for instructional supplies and equipment.

10. The project is described as Type I but is no budget for health and food services.

11. The project is described as either Type 2 or 5, but there are no increases in instruction, equipment, or the instructional environment factors.

12. The project is described as Type 3 but there are no service environment, pupil transportation, or student body activities changes.

13. The project is described as Type 4, but there is no health service budget entry or vice versa.

TABLE III

INTER-DATA-SET ERROR MESSAGES

1. Data about a grade j target group has been given. No data about a project aimed at that grade has been given.

2. Data about a project aimed at grade j has been given. No data about a target group in that grade has been given.

and of Projects X, Y, and Z be present and that there be agreement between the project and target group data sets as to which projects are aimed at which students. Table 3 shows the messages and tests that are made to determine if such ensembles of target groups and projects have been correctly related. Regardless of whether inter-set tests do or do not find legal relations, a report such as that shown in Figure 4 is generated showing how the simulation runs for a particular school system will be scheduled.

Once the pre-processor has run and has produced the cost, sequencing, and error reports, these reports are examined by the person responsible for the model run to determine whether corrections should be made in the data. If corrections are needed, then after they are made the data should be resubmitted to the pre-processor This cycle continues until an error-free deck is obtained. Once such a deck is obtained, the data go to the data base preparation section.

The data base preparation program is responsible for arranging the error-free data into a form acceptable and meaningful to the simulation. This involves two processes. The first of these is arranging the given data so that the logical requirements of the main model are satisfied; the second is adding those data whose values are either independent of school system or are applicable to most schools systems whose population are of a certain demographic type. Examples of such data are the probability matrices for the School Flow Submodel and the values for the various coefficients in the Instructional Process Submodel equations. These latter data are supplied to the data base preparation program from the master coefficient file which will have been previously compiled on the basis of research and expert judgment. Figure 5 indicates the pattern in which the various types of data are put for the main model's use.

Emphasis in the present Cost/Input Submodel design effort has been placed on providing a framework for providing cost and other data in a usable form to the user and to the instructional process, school flow, community, and the dropout/truancy submodels. It is felt that

SIMULATION SEQUENCE REPORT

SCHOOL SYSTEM: Ferndale, Mass.

The following combinations of projects and target groups will be evaluated:

Target Group Grade	Target Group I. D.	Project Name	Project I. D.
3	1000	Read Readiness	1
3	1000	Field Trips	2
4	1001	Field Trips	2
5	1002	Rem Reading	3

Figure 4

INPUT SEQUENCE TO THE MAIN MODEL

Mark Indicating School System Beginning

Master File Supplied Data

General School System Data

Number of Target Groups

1st Target Group Data

Number of Projects To Be Evaluated For 1st Target Group

1st Project Data

o o o

M^{th} Project Data

o o o

o o o

o o o

N^{th} Target Group Data

Number of Projects To Be Evaluated for N^{th} Target Group

1st Project Data

o o o

M^{th} Project Data

Figure 5

the actual operation and refinement of these models should occur before the development of more refined methods of assigning costs. As these models are tested, the desirability and utility of including present discounted value, typical particular item and package costs, projected support needs, and multiple year cost considerations--all of which involve considerable data reduction problems--will arise. The design described here serves as a starting point for a submodel that reflects how costs are actually used in the model and that provides a data input interface between the model and its users. Since the model serves this interfacing function, its further development depends on that of the model.

CHAPTER V

THE INSTRUCTIONAL PROCESS SUBMODEL

Central to the functioning of the overall cost-effectiveness model is the procedure for computing the immediate impact of a Title I project on the attitudes and achievements of its target population. This procedure is called the Instructional Process Submodel. It simulates the effects of changes in instruction and school services on student academic achievement, allowing two or more projects competing in a school district to be compared for their relative effectiveness.

Three assumptions underlie the Instructional Process Submodel. The first is that underachievement and lack of motivation among students from low-income homes is environmental rather than hereditary. The second assumption, following from the first, is that proper changes in the school environment--more personal services and better instruction--can contribute significantly to reducing learning difficulties and eventually improving student attitudes and performance. A more ambitious future model would also have to consider the impact of home and community changes on student achievement, but this is beyond the scope of the present effort.

Since the Instructional Process Submodel deals only with changes in the school environment and not with those of the home or community, its measures of effectiveness are relative rather than absolute. Thus, the third assumption of the submodel is that among Title I projects being compared, the home and community environments are and remain the same. The extent to which the ceteris paribus assumption does not hold is the extent to which effectiveness is measured relatively.

The Instructional Process Submodel changes achievement in response to Title I changes in two factors: (1) the overall effectiveness of instruction in the classroom, and (2) the resistance of the students to learning. The predicted achievement change is positively related to instructional quality and inversely related to student impedance to learning. In simplified form:

$$\triangle A = \frac{\triangle C}{\triangle Z} \qquad \text{where} \begin{cases} \triangle A = \text{change in achievement} \\ \triangle C = \text{change in instructional effectiveness} \\ \triangle Z = \text{change in student impedance to learning} \end{cases}$$

Title I programs are of two basic kinds, service-oriented and instruction oriented. The service programs affect the student impedance term by providing the student with medical and welfare attention. The instructional programs affect the instructional term through the improvement of the quantity and/or quality of instruction. If instructional effectiveness is increased or student impedance to learning is decreased, achievement will be improved.

Impedance to learning is determined for students as a function of six factors which are closely linked with underachievement. These factors are:

parental income level
parental education level
family solidarity
student handicap
student achievement level
peer achievement level

If a group of students have parents whose income level is very low and have had only an elementary education and if the students are far behind national norms in achievement and their peers are also far behind these norms, and if their fathers have deserted and their mothers work, and if the students all have some sort of physical handicap such as nearsightedness, then the value computed by the model for student impedance to learning would be near the maximum.

The effectiveness of instruction term if divided into the quantity and quality of instruction. Quantity of instruction is measured by classroom exposure time which combines duration and intensity of the index of instructional intensity and includes the teacher/student rat , text/student ratio, desks/student ratio, and the materials expenditure/student. Quality of instruction is an extremely difficult factor to isolate with data that is widely available data. It is calculated in the model by indicators such as the recency of curriculum materials and teacher effectiveness measures such as age, experience, and number of degrees received.

These, in brief, are the indicators used in calculating the change in achievement. These factors, being of primary important, are now covered in greater detail.

Many aspects of a student's environment affect his attitude toward school and his performance in the classroom. The variables that appear to be critical to the Instructional Process Submodel's outputs are the student's previous performance, his family background, the influence of his peers, the quality of the classroom and teachers, the interest of the curriculum, and the personal services provided by the school. For the model to operate, each of the considerations has to be described in such a way that all can be combined together and .

by the change components of a Title I project. Since there exists no standardized measure for any one of these environmental influences, the solution to this problem is to find appropriate numerical indices for each of the environmental characteristics.

One problem in the assignment of values to indices is that there is often wide disagreement among educational experts as to the value of particular teaching methods or curriculum materials.

The availability of data is another constraint on development of numerical indices in the model. Some indices not used might have been preferable to others used, but access to data through school records is limited. As a result, the final indices are the most accessible approximations to the environmental determinants of student achievement change.

These indices describe three groupings of variables: the student, the classroom, and the school. Title I projects are described in terms of the classroom and school indices. Each grouping consists of a set of indicators which are either influenced directly by Title I, as in the case of classroom and school categories, or are affected by Title I through the operation of the model, namely the student category. Below are the actual indicators used in each category:

Student	Classroom	School
parents' income	Δrecency of curriculum materials	Δpresence of service
parents' education level	Δteacher experience, age, number of degrees	Δ student exposure to service
physical handicap	Δteacher/student	Δspace/student
family solidarity	Δtext/student	Δparaprofessionals/ student
classroom peer under-achievement level	Δdesk/student	Δ\$ service materials/ student
own underachievement in basic skills	Δ\$ material aids/student	
	Δclassroom exposure time	

These indicators represent variables in the environment which are presumed to account for most of the variance in student attitude and achievement change. In the student category, it should be noted that though some of these indicators appear to be fixed with respect to Title I, they combine to represent attitudes which can in fact be affected by Title I. This attitude of negative disposition toward learning is referred to as <u>impedance</u> to suggest that a student's resistance to instruction is analogous to a circuit's impedance to current in electric circuit theory.

In the Instructional Process Submodel, classroom, school, and student indicators interact to give estimates of change in impedance and achievement levels. The assumption is that a student's sociological background, his performance record, his scholastic environment, and his future attitudes and achievements are intimately related. This is simply a restatement of two of the assumptions upon which the entire model is built.

These indicators alone are not sufficient to generate attitude and achievement changes. Some of the indices are more significant than others, and some become significant only when certain conditions obtain. How and to what extent all of these indicators relate to one another is the meat of the model. Exact quantitative relationships among the individual indicators do not exist in present educational theory. The model therefore will use expert judgments as to how much impedance decreases when Title I changes certain aspects of the environment and how much achievement increases in the face of decreasing impedance and increasing instructional effectiveness.

Changes in instructional effectiveness come about through the use of the instructional portion of the submodel. Title I projects are directed primarily at the classroom and are designed to improve the quality or to increase the quantity of the instruction the target students are receiving. The indicators listed under "Classroom" above are assumed by the model to account for most of the variance in achievement change that can be attributed to changes in instruction.

These indicators represent the significant influences the teacher, curriculum, and classroom are presumed to have on the change in student achievement. In the Instructional Process Submodel, they complement the influences of the personal services provided by the school. The indicators fall into two categories: those representing the quality of instruction, and those representing the quantity of instruction. The quality of instruction describes the interest level of the curriculum materials and the effectiveness of the teacher. Since neither of these lends itself immediately to objective or standardized measurement, indicators had to be chosen which would suggest the most salient aspects of curriculum and teacher quality.

In the case of the curriculum, it was felt that the "recency of materials" provided a fairly reliable indication of how interesting to a group of students a given curriculum was likely to be. Teacher effectiveness is measured in the submodel along three dimensions: age, experience, and number of advanced degrees. Research conducted by members of the Abt Associates staff revealed that teacher effectiveness correlated with no single characteristic of the teacher. A limited relationship was found for number of degrees received and experience. It also appeared to be true that very young and very old teachers generally performed less effectively than middle-aged teachers. The most desirable index would have been a measure of teacher aptitude or verbal facility, both of which have been found to be better indicators of teacher qualtiy. Unfortunately, neither type of data is commonly accessible. As a result, teacher quality is judged in the submodel as a combined index of age, experience, and degrees received.

The effectiveness of instruction is defined in the submodel not only by the quality of the teaching and the materials but also by the intensity and duration of contact between the student and the agents of his learning.

Quality of instruction, then, is complemented by the quantity of instruction that passes between teacher, curriculum, and student. Four numerical ratios were chosen to represent the amount of instruction receivable by the student. The first of these is the teacher/student ratio, which gives an indication of the amount of personal attention the student could receive in a given classroom situation. The efficiency of teaching in the classroom is heavily dependent upon the number of students with whom a single teacher has to deal. Another measure of the intensity of the student's interaction with the forces of learning is the text/student ratio. This index, along with the per-student expenditure on material aids for the classroom, represents the effort made by the school to provoke the curiosity of the student and to supply an outlet for such curiosity. The third ratio, the number of desks per student, is intended to reflect the physical conditions of the classroom and the freedom of movement allowed the students. Current thinking in education suggests that the ideal classroom is one in which the teacher has a comfortable number of students to teach, enough texts and materials to invoke and satisfy their curiosity, and uncramped conditions to give students a sense of individuality and sufficient privacy.

Classroom exposure time is the last of the instructional considerations in the submodel. If students do not have enough time to spend in classes which provoke their interest, then all the materials and teachers in the world will not produce enduring learning. Intensity of instruction must be coupled with extension of instruction to yield maximal results. A measure of the duration of instruction was thus incorporated into the submodel to round out the quantity of instruction index.

As presented above, the classroom and school variables are indicators of the actual changes in the students' environment that are caused by the introduction of a Title I project. The outputs of the submodel--changes in student attitudes and achievements--are based on these changes in the school environment and not on the absolute levels of instruction and service.

Instruction and service indicators act as constraints on one another in generating estimates of improved attitudes and increased achievement. For some students, the principal need is for improved instruction; for others, increased services. More often than not, service and instruction are interdependent for a given group of disadvantaged students and one without the other will prove futile. The Instructional Process Submodel accepts the school environmental changes introduced by Title I and interacts the characteristics of the target population with these improvements in services and instruction. The product of this interaction is the forecast of changes in attitudes and achievement resulting from the combined (where applicable) or separate efforts of the service and instructional components of a Title I project.

The impedance portion of the Instructional Process Submodel deals primarily with service programs. The Submodel receives a description of the school environment into which proposed Title I projects will be introduced. Environment as used here consists of an identification of the particular disadvantages of the target population, and an analysis of the level of instruction and the services provided by the school. The proposed Title I project is described in terms of the changes it purports to make in the level of instruction and in the amount or nature of service provisions. Service changes directly affect student disposition toward learning by negating some of the ill effects of a disadvantaged background. This results in an improvement in the student's attitude toward school, and with the instructional changes that have been introduced by Title I, the student level of underachievement is decreased, or in other words, his classroom performance is improved.

Some of the changes in the school environment may have little or nothing to do with the problems of the target population. Introducing guidance counselling for students whose principal need is proper medical care is one possible example of the potential mismatch between project and problem. An important step in the Instructional Process Submodel is matching the individual components of a proposed Title I project with the individual components of students' negative disposition to learning. Projects which are inappropriate for their target populations will produce little change in students' negative disposition to learning and, consequently, will have little effect upon student achievement.

Obviously, there are upper limits on the amount of actual attitude and achievement change that can take place. Reducing the student/ teacher ratio below some low number may indeed have very little additional effect. Having three psychologists for every pupil would also be of questionable value. As a result, the Instructional Process Submodel sets thresholds on the various environmental variables to prevent unattainable achievement changes from being forecasted. The model increases achievement only to grade norm, so that students who achieve grade level averages in any of the achievement categories are automatically unaffected by Title I changes. This saturation at grade norm emphasizes the fact that the model is pointed only toward students who are underachieving and is indifferent to better-than-norm results. Projects which bring their entire target populations to grade level are considered to be of maximum effectiveness in the model.

The Title I project is described by the indicators explained in the previous section for the level of instruction and the services provided by the target school, before the project itself is introduced into the model. Each component of the proposed project is then added to the classroom and school indicators to determine what changes will be made in the classroom and school environments. The individual environmental changes are weighted in accordance with their contributions to the variance in attitude and achievement change. Weighted service changes are combined linearly to produce the overall weighted change in service level and weighted instruction indicators are combined linearly to produce the overall weighted changes in instruction level.

At the same time, the Title I project identifies the particular disadvantages of its target population. These impedance indicators are weighted in accordance with their individual contribution to the student's negative disposition to learning. The weighted indices are then combined linearly to produce a "baseline" impedance for the students to be affected by the project.

Using "baseline" impedance and overall weighted service change, the Instructional Process Submodel computes an <u>Index of Potential Service Effectiveness.</u> This index represents the amount of impedance change that could take place in one year if every service improvement were relevant to the deficiencies of the target students. The principal assumption underlying the computation of this index is that the thrust of service components of a Title I project is to reduce impedance to learning. The computation further assumes that the effectiveness of service improvements is directly proportional to a student's "baseline" impedance and inversely proportional to his grade level. This means that a given service component is increasingly effective the higher the amount of learning difficulty in the target population, and decreasingly effective as the grade level of the target population increases. Potential effectiveness is also directly proportional to the amount of service change introduced by the project component.

Again using the individual disadvantages combined in "baseline" impedance and the overall weighted changes in school services, the model computes an <u>Index of Service Relevance.</u> This index represents the degree to which the individual service improvements match the individual disadvantages of the target population. Relevance itself is a binary concept; that is, a service component is either appropriate or inappropriate to an impedance characteristic. There are no middle values in the model.

Expected impedance change for the target population is then computed in a two-step process. First, the Index of Service Effectiveness is cross-multiplied by the weighted Index of Service Relevance. The weight for the Relevance Index is the sum of the indivudual weights of each characteristic of impedance that is matched by a service improvement. The product of the two indices, Relevance and Effectiveness, is the maximum impedance change that service improvements could achieve. Impedance represents student attitudes, and there is a practical limit on the amount of change that can occur in a year's time. The second step in the computation of impedance change, then, is a comparison between the calculated maximum and the practicable threshold. The model assumes that this threshold on impedance change is directly proportional to the "baseline" impedance level. This assumption simply reiterates the previous one that Potential Service Effectiveness increases as the amount of learning difficulty increases. It also implies, however, that no service improvement, at least in terms of the model, is relevant to students with "baseline" impedances equal to zero (which underlines the fact that the model operates only on those students who have positive impedances). The threshold itself is called the "Practical Limit on Impedance Decline" and is described as a function of "baseline" impedance. The eventual impedance change forecasted by the model is limited to the threshold value if the product of the two indices exceeds it, or the product of the two indices if they are below threshold value.

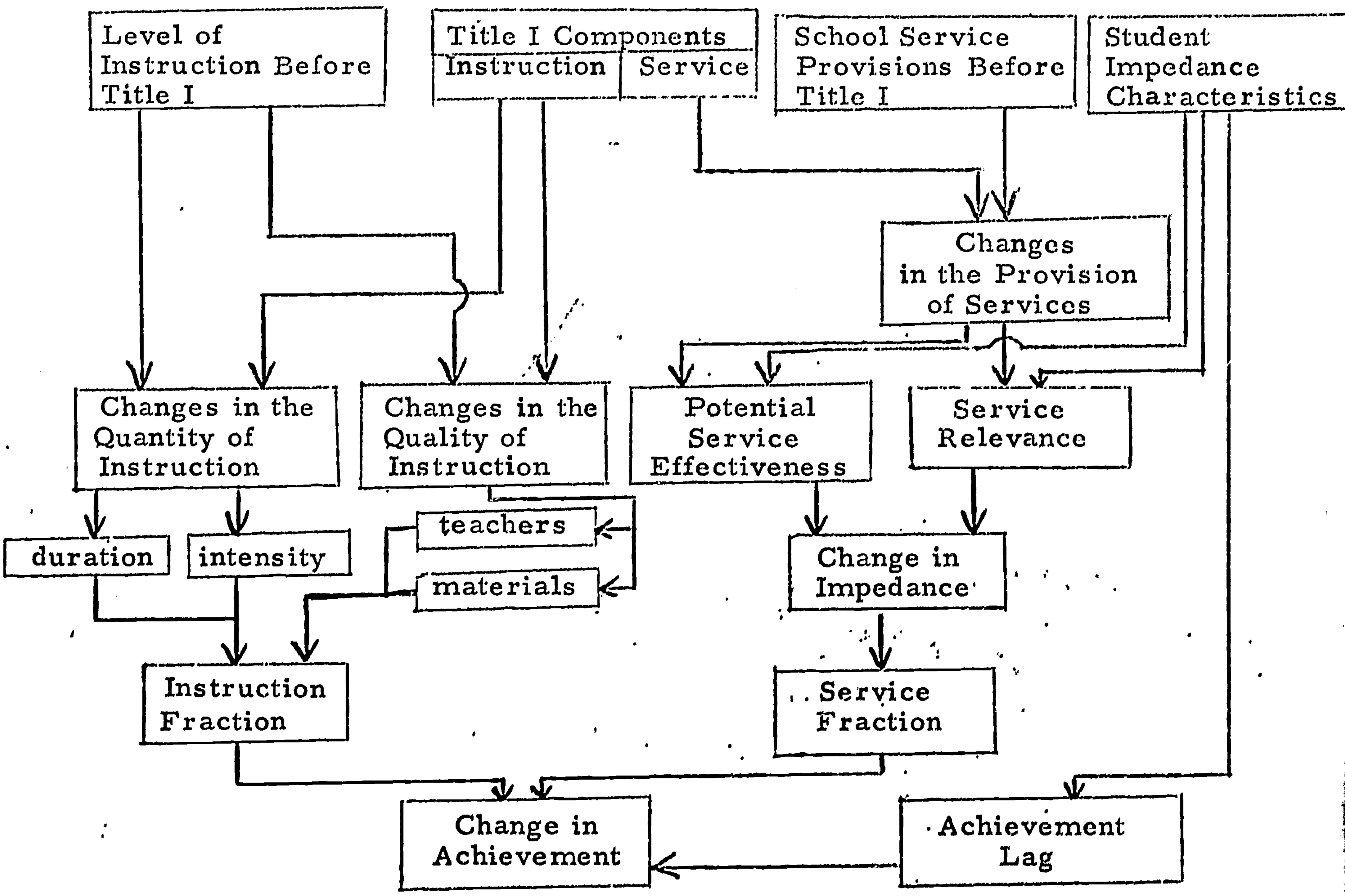
The contribution of a change in impedance to ultimate change in the achievement level of the target population is called the Service Fraction. The computation of this fraction assumes that achievement change is directly proportional to the reduction in impedance and inversely proportional to the "baseline" impedance. The Service Fraction, then, varies directly as the proportional change in impedance.

Up to this point, the description of the Instructional Process Sub-model has concerned itself only with the impact of service improvements on student impedance and the impact of impedance change on achievement. There are, however, instructional components to Title I projects which affect achievement levels directly. The conversion of these instructional components into contributions to achievement change proceed in parallel with the service computations.

The Instruction Fraction is the contribution to achievement change made by Title I improvements in the level of instruction. The computation of this fraction assumes that changes in achievement are directly proportional to the amount of change in the instructional level. Since, by definition, impedance retards achievement, the Instruction Fraction varies inversely as the "baseline" impedance of the target population. This means that the Instruction Fraction is the amount by which achievement would change if impedance were held constant. Title I projects deal exclusively with instructional improvements, the Instruction Fraction is the only agent of achievement change. Title I projects that comprise both instruction and service improvements combine the two fractions in the computation of ultimate achievement change.

Final achievement change is computed by adding the fractional achievement contributions of service and instruction improvements and multiplying their sum by the "achievement lag". The "achievement lag" is the number of grade levels the target group lagged behind their grade norm in achievement. For the purposes of the Instructional Process Submodel, this lag represents the maximum achievement improvement that a Title I project can produce with a given target population. In most cases, the sum of the two fractions will be less than one, and some of the lag will remain. If the sum of the two fractions equals or exceeds one, then the lag will have been entirely eliminated and the model will saturate achievement at grade norm. As mentioned before, the Instructional Process Submodel does not differentiate among competing projects which yield achievement changes greater than the students' lag behind grade norm.

Below is a flow chart of the model process:



Final impedance and achievement changes are the outputs of the Instructional Process Submodel. Both are input into the School Flow Model to determine the long-range impact Title I projects will have on their target populations. If the same project is applied in successive years, the Instructional Process and School Flow models are simply iterated by entering the previous cycle's results for each simulated year. Changes in impedance and achievement are thus accumulated over time.

Mathematical Specification of the Instructional Process Submodel

The quantitative description of the Instructional Process Submodel is divided into four parts. The first part explains how the submodel mathematically converts the specifications of Title I proposals into their instructional and service components. The second part describes the operating characteristics of the target population. Part three describes how improvements in the service environment of the school affect the impedance of the target population. Finally, part four gives the mathematical format for computing ultimate achievement change from the change in impedance and the Title I changes in the instructional environment.

Some prefatory information is helpful in understanding how the mathematical relationships were derived for each section of the model.

The Office of Education classifies its Title I projects as service or instructional. Service projects include special classes for the handicapped, guidance counselling, free lunch programs and, in general, changes in the school designed to increase a student's health or his personal welfare. Instructional projects, on the other hand, concern themselves with the educational and cultural enrichment of their target populations. Typical instructional projects are special reading programs, reducing class size, and preschool education. In the Instructional Process Submodel, proposed projects are broken down into their component parts and these are assigned to either the classroom or school indicators. Projects that cross over the Office of Education classification boundary, such as tutoring for slow learners, therefore contribute to both the service and instructional fractions in the model.

Part two, which describes the disadvantaged student, consists of six sociological and physiological indicators which correlate highly with scholastic failure. The model presumes not only that the negative effects of these disadvantages can be neutralized but that their neutralization will account for most of the variance in ultimate achievement change.

When the Title I projects interact with their target populations, qualitative change in the latter is assumed to take place. The size of the change is dependent upon the receptivity of the affected students to the particular environmental changes. This means that students who are ill-prepared to learn will be generally unresponsive to instructional changes such as curriculum innovations. Certain minimum changes in services, depending on the nature of the students' deficiencies, have to be provided by the school before any progress in learning can occur. Whether achievement improves or not therefore depends upon whether the minimum service changes have occurred and whether the instructional changes are high enough to match the increase in student receptivity.

From the above discussion, the Submodel derives the relationship between achievement, instructional level, and impedance which forms its foundation. If instruction is thought of as the driving force of education, and impedance as the student's resistance to this force, then achievement can be mathematically described as the quotient of the two. Achievement increases as the level of instruction increases and decreases as impedance increases. Title I can thus affect achievement by increasing instructional levels, by decreasing impedances, or by both.

1.0 Title I

Each Title I project is evaluated in terms of its effect on the school service environment, and its effect on the level of instruction.

Separate indices will be defined for these two effects and evaluated for each Title I project.

Each index is described by two components: quality and quantity. Quantity is further decomposed into intensity and duration.

1.1 The Service Subroutine

The Service Subroutine assigns to each Title I project an index value which reflects the changes in the school service environment caused by the project. Following are detailed descriptions of the two components of the service index, quality and quantity, showing also how they are weighted and combined.

Quality of Service

The first component in the service index is concerned with changes in the quality of service provided. Quality is measured by two factors:

1. Whether or not Title I has introduced a new activity; and
2. Whether or not the program is provided to the student without charge.

A Title I program that upgrades or augments existing school services, increasing the number of guidance counselors/student for example, will be measured as a change only in quantity rather than as a change in both quality and quantity. A program providing a new service will, in general, have much greater effect on the target group. This so-called Hawthorne effect has been modelled, so that a new program will be more effective than an upgraded program, all other things being equal.

A positive value of one is assigned when either of the two factors is present; otherwise, a value of zero. The "ones" are weighted, and added, to yield an index of the change in the quality of service provided by Title I. The weighting coefficients are established on the basis of research findings or judgment.

The final form of the equation is:

$$\triangle Q_S = q_1' \begin{pmatrix} P = 1\text{: Absence of prior programs} \\ P = 0\text{: Otherwise} \end{pmatrix} + q_2' \begin{pmatrix} F = 1\text{: Program free to students} \\ F = 0\text{: Otherwise} \end{pmatrix}$$

q_1' and q_2' are the weighting coefficients which also normalize $\triangle_{Q_S}$ to a value between 0 and 1.

Quantity of Service

The second component in the service index is concerned with changes in the quantity of service provided. Quantity is determined by changes in the intensity of service, e.g., increasing the numbers of professionals/student; and by changes in the duration of service, e.g., increasing the number of hours/day in which the service is provided.

Intensity of Service

The change in the intensity of instruction ($\triangle_{I_s}$), is expressed in terms of three weighted ratios which define the school service environment after Title I. Changes in the numbers of personnel, changes in the square feet of space available and changes in the dollars spent on materials are measured. Each term is then divided by the number of students. Each of these quotients can be related to specific Title I Programs such as increasing the counseling staff, expanding the size of plant and equipment, or providing new or improved services such as lunch, milk, remediation equipment and trips to museums. In addition, two interaction terms are provided for cases in which the quality of professional service is low or insufficient in the school (i'_4), and for cases in which conditions are cramped and materials scanty (i'_5).

The final form of the equation is:

$$\Delta I_s = i'_1 \frac{\Delta \text{\#'s of professionals}}{\text{student}} + i'_2 \frac{\Delta \text{ sq. ft. of space}}{\text{student}}$$

$$+ i'_3 \frac{\Delta \text{\$ spent on materials}}{\text{student}} + i'_4 + i'_5$$

The weighting coefficients (i') normalize ΔI_s to a value between 0 and 1. Relative weightings for each coefficient are determined by research or judgment.

Duration of Service

The duration component measures the difference between the student exposure to service before and after Title I in hours/year. Exposure is measured in hours/day, days/week, and weeks/year. Each time element in then compared against a time threshold equal to the attention span of the target group. Projects which exceed these thresholds will yield diminishing returns to scale.

The equation for the difference in duration of service is:

$$\Delta D_s = d' \left(H'_s \; D'_s \; W'_s - H_s D_s W_s \right)$$

where H'_s, D'_s and W'_s represent the thresholded values after Title I in hours/day, days/week, weeks/year, respectively, and H_s, D_s, and W_s represent their counterparts before Title I.

d' normalizes the expression to a value between 0 and 1.

Index of the Value of Title I Service Offered

Quality, intensity, and duration of service are weighted and combined into a value of service index (ΔS) as follows:

$$\Delta S = s_1 \Delta Q_s + s_2 \Delta I_s + s_3 \Delta D_s$$

The weighting coefficients (s) normalize ΔS to a scale of 0 to 1, in addition to providing a relative importance weight for each term (in accordance with each term's contribution to variance in impedance).

TABLE 1.1

The Service Submodel

Name	Variable	Type	Range	Source
Goodness of service index	Δs	Fraction	0-1	Computed
Service weights	s_i	Empirical Constants	Depends on Variance	Civil Rights Survey
Change in service quality	ΔQ_s	Fraction	0-1	Computed
Quality weights	q_i'	Empirical Constants	Depends on Variance	Civil Rights Survey
Absence of prior program Program free to students	P F	Measured Constants After Title I	0 or 1	Civil Rights Survey
Change in service intensity	ΔI_s	Fraction	0-1	Computed
Intensity weights	i_i'	Empirical Constants	Depends on Variance	Civil Rights Survey
Change in #'s of professionals Change in sq. ft. of space Change in $ spent on materials	Components of Intensity	Measured Constants After Title I	Fractions	Title I data
Difference in Service Duration	ΔD_s	Fraction	0-1	Computed
Duration Weight	d'	Empirical Constant	Depends on Variance	Civil Rights Survey
Thresholded service environment hours/day, days/week, weeks/yr. after Title I	H_s', D_s', W_s'	Measured Constants After Title I	Fractions	Title I data
Environment before Title I	H_s, D_s, W_s	Measured constants before Title I	Fractions	Title I data

<u>Summary of Equations</u>

$$\Delta S = s_1 \Delta Q_s + s_2 \Delta I_s + s_3 \Delta D_s$$

$$\Delta Q_s = q_1' \text{ (1 if no prior program) } + q_2' \text{ (1 if Free) } \left[1 + \text{(1 if parents' income} \leq \$2000) \right]$$

$$\Delta I_s = i_1' \frac{\Delta \text{\#'s of professionals}}{\text{student}} + i_2' \frac{\Delta \text{ sq. ft. of space}}{\text{student}} + i_3' \frac{\Delta \$ \text{ spent on mat.}}{\text{student}} + i_4' + i_5'$$

$$\Delta D_s = d' (H_s' \cdot D_s' \cdot W_s' - H_s \cdot D_s \cdot W_s)$$

1.2 The Instructional Subroutine

The Instructional Subroutine assigns to each Title I project an index value which reflects the changes in the level of instruction caused by the project, in much the same way that the Service Subroutine assigns an index reflecting changes in the school service environment.

Expected achievement improvements are dependent upon the quality and quantity of instruction. Title I may affect each of these separately or in combination. Each component is described in detail showing how it can be weighted and combined with the others into an index of the change in instruction afforded by the Title I programs.

Quality of Instruction

The change in the quality of instruction, ΔQ, is decomposed into two factors:

ΔREC:	Index of the change in recency of curriculum materials measured by the average difference in publication dates; and
ΔQ_t:	Index of the change in teacher quality measured by the change in teacher experience in years.

Each of the two factors is weighted according to the achievement variance accounted for. "Recency" and teacher "quality" are not linearly related. For example, when curriculum materials are antiquated, the effectiveness of the teacher becomes even more crucial in the students' education. Thus, the change in the quality of instruction ΔQ, is dependent not only on changes in recency and teacher quality, but also on the interaction of the two, when recency is less than a threshold ϕ.

The final form of the equation is:

$$\Delta Q = q_1 (\Delta REC) + q_2 \cdot \Delta Q_T \left[1 + \begin{cases} 1 \text{ if } \Delta REC \leq \phi \\ 0 \text{ Otherwise} \end{cases} \right]$$

The weighting coefficients (q) normalize ΔQ to a value between 0 and 1, in addition to accounting for the variance associated with each term.

Quantity of Instruction

The second component in the instructional index is the quantity of instruction provided. Quantity is determined by changes in the intensity of instruction, e.g., increasing the number of teachers/student, and by changes in the duration of instruction, e.g., adding a remedial reading program.

Intensity of Instruction

The change in the intensity of instruction, (ΔI), is expressed in terms of four weighted ratios which define the instructional environment after Title I. Interaction terms are used when teacher mastery is low (i_5), when classroom conditions are cramped and instructional materials scanty (i_6), and when the class size is too large or the number of teachers is inadequate (i_7).

The final form of the equation is:

$$\Delta I = i_1 \frac{\Delta \#\text{'s of teachers}}{\text{student}} + i_2 \frac{\Delta \#\text{'s of texts}}{\text{student}} + i_3 \frac{\Delta \#\text{'s of desks}}{\text{student}}$$

$$+ i_4 \frac{\Delta \$ \text{ spent on aids}}{\text{student}} + i_5 + i_6 + i_7$$

The weighting coefficients (i) normalize ΔI to a value between 0 and 1. Relative weightings for each coefficient are determined by research or judgment.

Duration of Instruction

The duration component measures the difference between student exposure to instruction before and after Title I in hours/year. Exposure is decomposed into hours/day, days/week and weeks/year. Each time element is compared against a time threshold equal to the attention span of the target students. Projects which exceed these thresholds will yield diminishing returns to scale.

The equation for the difference in duration of instruction is:

$$\Delta D = d\,(H' \cdot D' \cdot W' - H \cdot D \cdot W)$$

where H', D' and W' represent the thresholded values after Title I in hours/days, days/weeks, and weeks/year respectively, and H, D, and W represent their counterparts before Title I. d normalizes the expression to a value between 0 and 1.

Index of the Change in Instruction

Quality, intensity and duration are weighted and combined into an index of change in instruction (ΔC) for each category of achievement (j) as follows:

$$\Delta C_j = c_{1_j} (\Delta Q) + c_{2_j} (\Delta I) + c_{3_j} (\Delta D)$$

The weighting coefficients (c_j) normalize ΔC to a scale of 0 to 1, in addition to accounting for the variance in each achievement category (j).

TABLE 1. 2

The Instructional Subroutine

Name	Variable	Type	Range	Source
Change in instruction by Title I	ΔC_j	Fraction	0 - 1	Computed
Achievement category weights	$C_{i,j}$	Empirical constant	Depends on the amount of variance accounted for each factor	Civil Rights Survey research findings
Change in instructional quality	ΔQ	Fraction	0 - 1	Computed
Quality weights	q_i	Empirical	Depends on variance	Civil Rights Survey research findings
Recency threshold	ϕ	Empirical	Depends on recency	Civil Rights Survey
Index of the change of curriculum materials I Index of the change in teacher quality	ΔREC, ΔQ_T	Measured constants after Title I	Fractions	Title I data
Change in instructional intensity	ΔI	Fraction	0 - 1	Computed
Intensity weights	i_i	Empirical constants	Depends on variance	Civil Rights Survey
Number teachers/student Number texts/student Number desks/student Dollars spent on aids/student	Components of Intensity	Measured constants after Title I	Fractions	Title I data
Difference in instructional duration	ΔD	Fraction	0 - 1	Computed
Duration weight	d	Empirical constant	Depends on variance	Civil Rights Survey
Threshold instruction environment hours/day, days/week, weeks/year after Title I	H', D', W'	Measured constants after Title I	Fractions	Title I data
Same environment before Title I	H, D, W	Measured constants before Title I	Fractions	Title I data

Summary of Equations

$$\Delta C_j = c_{1_j} \; \Delta Q + c_{2_j} \; \Delta I + c_{3_j} \; \Delta D$$

$$\Delta Q = q_1 \; \Delta REC + q_2 \; \Delta Q_t \left[1 + \begin{pmatrix} 1 \text{ if } \Delta REC \leq \phi \\ 0 \text{ Otherwise} \end{pmatrix} \right]$$

$$\Delta I = i_1 \frac{\Delta \text{\#'s of Teachers}}{\text{student}} + i_2 \frac{\Delta \text{\#'s of texts}}{\text{student}} + i_3 \frac{\Delta \text{\#'s of desks}}{\text{student}}$$

$$+ i_4 \frac{\Delta \text{\$ spent on aids}}{\text{student}} + i_5 + i_6 + i_7$$

$$\Delta D = d(H' \cdot D' \cdot W' - H \cdot D \cdot W)$$

2.0 The Disadvantaged Student

The target population is characterized by a set of six factors of disadvantage which, when aggregated, constitute its "baseline" impedance to instruction. This impedance is expressed as an index of values between 1 and 10 and is denoted by the letter Z. When operated upon by appropriate service components of a Title I project, Z decreases and this decrease becomes the service contribution to achievement change.

Baseline Calculations: The Index of Students' Impedance to Instruction

A particular student population is targeted for a Title I project. This population is characterized by certain educational deficiencies which are referred to as the students' "baseline impedance." Impedance may be academic, psychological, sociological, or combinations of these. In all cases, however, it represents the students' resistance to instruction. The Title I project is intended to alter the students' scholastic environment in such a way as to offset these existing disadvantages. Changes are made in the quality and/or quantity of instruction, in school services, or in both at the same time. What is expected is a reduction in the students' achievement gap and a reduction in their impedance to instruction. Impedance will be measured for each of the student types (t) comprising the target population. These baseline (B) values will be symbolized as: $Z_{B,t}$.

Impedance to instruction is decomposed into the following six factors:*

\$	Income of Parent	(\$2000 or less, or other)
E_p	Parents' education level	(Elementary or other)
H	Handicap	(Physical, mental or emotional)
S	Solidarity of family	(Disrupted or intact)

*See Benjamin S. Bloom, Stability and Change in Human Characteristics, New York: Wiley, 1964; especially Chapter 4.

L_c — Grade/Achievement lag for the cohort. The cohort contains all the students in the same class, or in the same grade, in the target school.

L_s — Grade/Achievement lag for the student in the basic skills of reading, language and math.

Each of these factors is converted to an index value of 0 or 1 and then weighted by the amount of variance it accounts for in determining changes in achievement. The index of impedance to instruction ranges from 1 to 10 and is described by the equation:

$$
\begin{aligned}
Z_{B,t} = 1 + (a) \Bigg\{ & (z_1)\begin{pmatrix} \text{1 if Parents' income is} \leq \$2000 \\ \text{0 Otherwise} \end{pmatrix} \\
& + (z_2)\begin{pmatrix} \text{1 if Parents' education is elementary} \\ \text{0 Otherwise} \end{pmatrix} \\
& + (z_3)\begin{pmatrix} \text{1 if Handicapped} \\ \text{0 Otherwise} \end{pmatrix} + (z_4)\begin{pmatrix} \text{1 if family disrupted} \\ \text{0 Otherwise} \end{pmatrix} \\
& + (z_5)\begin{pmatrix} \text{1 if cohort lag is} \leq 3 \\ \text{0 Otherwise} \end{pmatrix} + (z_6)\begin{pmatrix} \text{1 if student lag is} \leq 3 \\ \text{0 Otherwise} \end{pmatrix} \\
& \left[1 + \begin{pmatrix} \text{1 if Parents' education is elementary} \\ \text{0 Otherwise} \end{pmatrix} \right] \Bigg\}
\end{aligned}
$$

with $a = \dfrac{9}{\sum_{i=1}^{6} z_i}$ normalizing the term.

If the students' parents have less than a secondary education, the significance of the students' achievement lag in the basic skill areas is increased. With poorly educated parents, a student's need for achievement is far less likely to be high.*

These interactions between factors are accounted for by including (as part of the sixth term in the impedance equation) an additional element:

*R. H. Dave, The Identification and Measurement of Environmental Process Variables that are Related to Educational Achievement, Unpublished Ph.D. Dissertation, University of Chicago, quoted in Bloom, Ibid., p. 124.

(z_6) (1 if student lag is $\leq$ 3) (1 if parents' education is elementary)

The value 3 is derived by using research results that show a lag of one grade level by the third grade, two by the sixth grade, three by the ninth, and four by the twelfth are on the critical path toward failure.

TABLE 2.0

Index of the Student's Characteristic Impedance to Instruction

Name	Variable	Type	Range	Source
Index of Impedance to instruction	$Z_{B,t}$	Index value	1 - 10	Computed
Normalizing constant	a		Depends on the sum of z weights	Computed
Impedance component weights	z_1 to z_6	Empirical constant	Depends on the amount of variance accounted for each factor	Civil Rights Survey
Income of Parent Education level of parent Handicap Solidarity of family Grade/lag for cohort Grade/lag for student	\$ E_p H S L_c L_s	Measured constants before Title I	0 or 1	School Data

Summary of Equations

$$Z = 1 + a \sum_{i=1}^{5} z_i D_i + z_6 (1 \text{ if } L_s \leq 3) \left[(1 \text{ if } E_p = \text{elementary}) + 1\right]$$

where D_i are the disadvantage factors.

3.0 The Model Environment

In this section the amount of disadvantage removed by the Title I project is computed. The equations involve the conversion of the Title I service index, (ΔS), into an index of impedance change, (ΔZ). Three concepts are involved:

1. a measurement of the effectiveness of service (quantity);
2. a measurement of the relevance of that service to reducing the disadvantage (quality); and
3. the combination of quantity and quality into an index of impedance change limited by a behavior threshold for the target group.

The following assumptions are made:

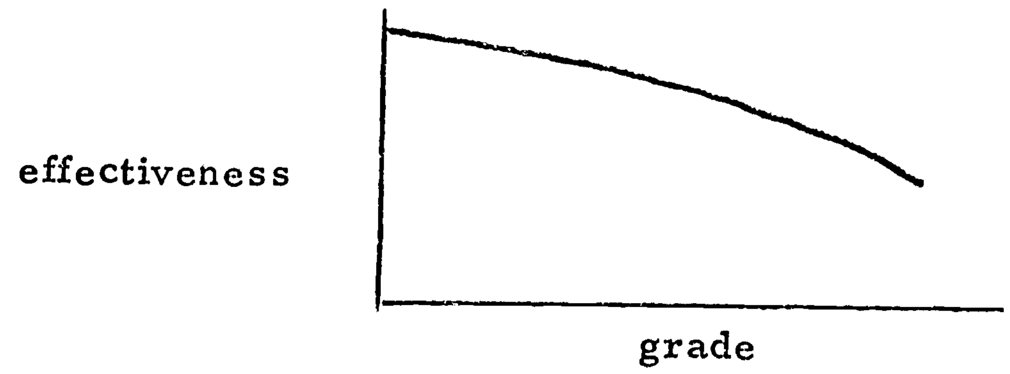
1. The effectiveness of a Title I service program is reduced when the program is introduced in the later grades;* however, this effect is lessened when the student impedance is high.
2. Different Title I service programs tend to reduce the factors of instructional impedance differentially; i.e., the programs operate to different degrees upon students having different impedance makeups.*
3. The amount by which the student impedance can change in any one year period is dependent upon the student impedance level. As a corollary to this assumption, there is no Title I program which is relevant to a student possessing no characteristics of disadvantage.

3.1 Service Effectiveness

The service effectiveness factor is computed by combining the potential service provided by Title I with the particular target group it affects. Assumption 1 (see section 3.0) asserted that the effectiveness of Title I service will be reduced at higher grade levels. This reduced effectiveness should not be confused with the factors making the Title I program relevant to the student's particular disadvantage. (See sec. 3.2)

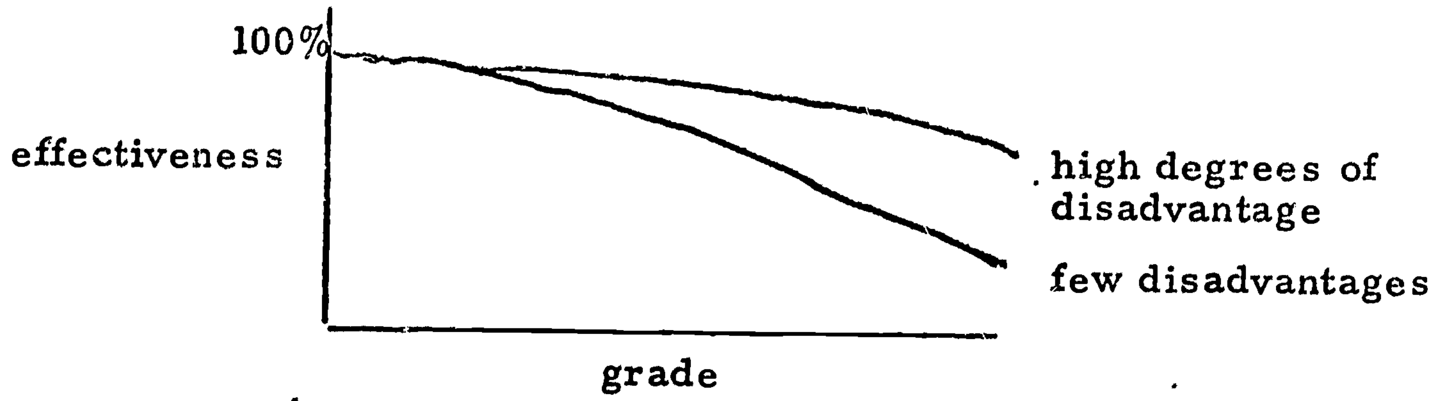
*Bloom, Ibid., pp. 125-126.

In graphical terms, the potential effectiveness of a given Title I service component drops off with grade at an accelerating pace:



When the target student has a high level of impedance to instruction, he is assumed to be more receptive to a given Title I service improvement regardless of when it is applied.

These two effects apply differentially to students with different degrees of disadvantage. Effectiveness is reduced most for students with few disadvantages at the latest grades:



The equation for the service effectiveness factor represents the quantity of additional service afforded a specified target group by Title I. The numerator, ΔS, the value of service index, is a function only of Title I and was described in section 1.1. The denominator is a function of the impedance of the target group (ΔZ), described in section 2, and the target group grade.

The equation for the service effectiveness factor is:

$$E_s = \frac{\Delta S}{\left[1 + \left(\frac{G-1}{Z}\right)^2\right]}$$

3.2 Service Relevance

Assumption 2, of section 3.0, stated that different Title I programs would produce different effects on different students. In the model, the quality of the Title I school service, as it relates to the target population, is determined by a set of relevance numbers (0 and 1) which indicate the specific factors of disadvantage directly affected by the Title I program. Each Title I service program, whether free lunch, professional service, or special programs for the handicapped, will attempt to attenuate the characteristics of disadvantage to different degrees.

Two factors are involved: the specific characteristics making up each student's impedance and secondly, the specific impedance characteristics to which the Title I program is relevant. When the two sets of factors are identical, the relevance of service will be at a maximum; when they are disparate, the relevance approaches zero.

3.3 The Change in Impedance (ΔZ), caused by Title I.

When the two factors, service quantity and quality, are combined, they produce an index of impedance change, ΔZ, caused by Title I. Relevant (R) components of impedance are weighted and added together. After being normalized, this sum is multiplied by the service effectiveness factor (E_s) to produce an index of the change in impedance (ΔZ).

$$\Delta Z = (a)\,(E_s)\left\{ R_1 \left[z_1 \begin{pmatrix} 1 \text{ if Parents' income is} \leq \$2000 \\ 0 \text{ Otherwise} \end{pmatrix} \right] + \right.$$

$$R_2 \left[z_2 \begin{pmatrix} 1 \text{ if Parents' education is elementary} \\ 0 \text{ Otherwise} \end{pmatrix} \right] +$$

$$R_3 \left[z_3 \begin{pmatrix} 1 \text{ if handicapped} \\ 0 \text{ Otherwise} \end{pmatrix} + R_4 \left[z_4 \begin{pmatrix} 1 \text{ if family disrupted} \\ 0 \text{ Otherwise} \end{pmatrix} \right] +\right.$$

$$R_5 \left[z_5 \begin{pmatrix} 1 \text{ if cohort lag is} \leq 3 \\ 0 \text{ Otherwise} \end{pmatrix} \right] +$$

$$\left. R_6 \left[z_6 \begin{pmatrix} 1 \text{ if student lag is} \leq 3 \\ 0 \text{ Otherwise} \end{pmatrix} \left(1 + \begin{pmatrix} 1 \text{ if Parents' ed. is elem.} \\ 0 \text{ Otherwise} \end{pmatrix} \right) \right] \right\}$$

where: E_s is the service effectiveness factor (section 3.1)

R_1 to R_6 are the relevance numbers (section 3.2)

The multiplier (a), normalizes the term to a value between 0 and 9 (see section 2.0 for detail).

z_1 to z_6 are the same disadvantage factor weights described in section 2.0

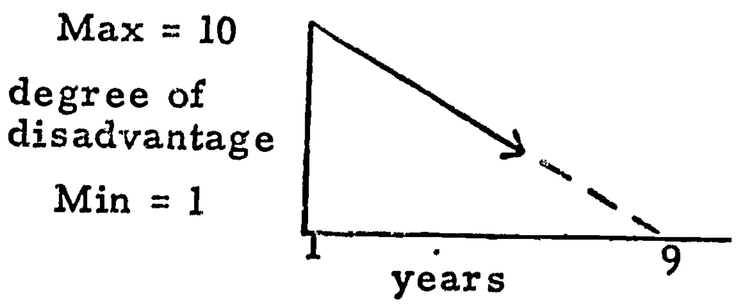
The relevance numbers R_1 to R_7 are determined by the Title I program in terms of which impedance factors the Title I project can overcome.

3.4 Maximum Allowable One-Year Change in the Impedance Value Caused by Title I

Assumption 3, section 3.0 implied that there was an upper bound on the amount of impedance change that could be expected in the target population after a one-year exposure to a Title I program. It is further assumed that this upper limit is directly related to the baseline impedance. The greater the impedance, the greater the potential impedance change, all other things being equal.

Included in assumption 3 is a corollary stating that there is no Title I program which is relevant to a student having zero impedance. This assumption is necessary in the model because a bounded index scale is needed to prevent Title I from causing impedance to go outside the index scale. The boundaries are Z_{min} and Z_{max}.

A student possessing all six disadvantage factors is subject to the maximum rate of impedance decline. Lesser "baseline" impedance yield lesser maxima.



The above curve approximates the removal of one factor of disadvantage per year.

The equation describing the maximum rate of decline is:

$$M = \frac{Z - Z_{min}}{6\left[1 + \frac{Z^2}{2 Z_{max}^2}\right]} \qquad Z_{min} = 1 \qquad Z_{max} = 10$$

3.5 Final Value for the Change in Impedance

As a final step in computing the reduction in impedance by the Title I project, the index value, ΔZ, computed in section 3.3 must be limited by the boundary value M computed in 3.4.

ΔZ is compared against the Value M. When ΔZ is larger than M, it is changed to equal M. The need for this change will probably be greatest when the students' impedance is low.

TABLE 3.0

The Model Environment

Name	Variable	Type	Range	Source
Service Effectiveness Factor	E_s	Fraction	0-1	Computed (3.1)
Index of the goodness of Title I service	S	Fraction	0-1	Computed (1.1)
Index of Impedance	Z	Index value	1-10	Computed (2.0)
Change in Impedance caused by Title I	Z	Index value	1-10	Computed (3.2 or 3.4)
Normalizing constant	a	———	Depends on the sum of z weights	Computed (2.0)
Relevance	R_1 to R_6	Measured constants	0-1	Empirical Research or judgment
Impedance Component Weights	z_1 to z_6	Empirical constants	Depends on the amount of variance accounted for each factor	Civil Rights Survey
Income of Parent Education level of parent Handicap Solidarity of Family Grade/lag for cohort Grade/lag for stu.	\$ E_p H S L_c L_s	Measured constants before Title I	0 or 1	School Data
Maximum allowable one-year change	M	Fraction	0-1	Computed (3.4)

Summary of Equations

$$E_s = \frac{\Delta S}{1 + \left(\frac{G-1}{Z}\right)^2}$$

$$Z = a\ E_s\left[\sum_{i=1}^{5} R_i z_i D_i + R_6 z_6\ (1 \text{ if } L_s \leq 3)\right]\left[(1 \text{ if } E_p = \text{elementary}) + 1\right]$$

D_i are the characteristics of Impedance

$$M = \frac{(Z-1)}{6\left[1 + \frac{Z^2}{200}\right]}$$

4.1 The Change in Achievement

Title I is described in terms of instructional and service changes. Either, or both, of these kinds of changes may be present in any Title I project. It is now assumed that the achievement lag can be attributed to the students' impedance and to the level of instruction itself. Adverse effects on achievement due to impedance factors can be reduced by properly applied and relevant Title I service components, while the adverse effects of poor instruction can be reduced by properly applied and relevant Title I instructional components.

This leads to the following relationship: achievement is directly proportional to instruction, and inversely proportional to impedance. Two fractions are defined to represent the contributions of service (F_s) and instructional (F_i) improvements.

Instruction Fraction

Achievement = C/Z, where C describes the level of instruction and Z the student impedance to instruction. F_i is the fractional instruction change caused by Title I.

$$F_i = \frac{\Delta C}{Z}$$

ΔC is the index of instruction from section 1.2

Service Fractions

To find the corresponding change in achievement caused by reduced impedance, the difference before and after Title I is computed:

$$F_s = \frac{C}{(Z - \Delta Z)} - \frac{C}{Z}$$

This equation can be rearranged to read:

$$F_s = \frac{C}{Z} \quad \frac{\Delta Z}{Z - \Delta Z}$$

4.2 The Change in Achievement

Final achievement change is:

$$\Delta A = (F_i + F_s) \cdot \text{Lag}$$

where "Lag" is the number of grade levels the target group lags behind grade norm in achievement, and represents the model's upper bound on possible performance improvement.

4.3 The Model and Time

This description of the Instructional Process Model assumes that calculations are made for a one year period. In situations where a Title I project acts on an entire school system, or for a period of successive years, the Instructional Process model must be re-entered each year with new data, describing the target group's previous achievement lag. The feedback of these data each year allows computation of the cumulative change in achievement.

TABLE 4.0

The Change in Achievement

Name	Variable	Type	Range	Source
The Change in Achievement	ΔA	Forecasted Variable	0-8 grade levels	Computed (4.2)
Index of the Change in Instruction Caused by Title I	ΔC	Index	0-1	Computed (1.2)
Change in impedance caused by Title I	ΔZ	Index	1-10	Computed (3.3)
Index of student impedance to instruction	Z	Index	1-10	Computed (2.0)
Student achievement lag	Lag	Measured Constant before Title I	0-8 grade levels	School Data
Fractional instr. change Fractional ser. change	F_i F_s	Fraction	0-1	Computed (4.1)

Summary of Equations

$$\Delta A = \left[\frac{\Delta C}{Z} + Lag\left(\frac{\Delta Z}{Z-\Delta Z}\right)\right] \cdot \text{Gap} = (F_i + F_s) \cdot \text{Gap}$$

CHAPTER VI

THE SCHOOL FLOW SUBMODEL

This chapter describes a mathematical model which predicts the achievement levels of students at each grade in their school careers subsequent to the grade of Title I intervention. Evaluation of the immediate effect of a proposed Title I program is discussed in Chapter V. The procedure in this chapter extrapolates achievement forward in time from the point at which the Title I program is no longer present in the school. By comparing the achievement levels extrapolated from the effects of a proposed Title I program with those extrapolated without a Title I program, we can assess the differential effects of the proposed assistance.

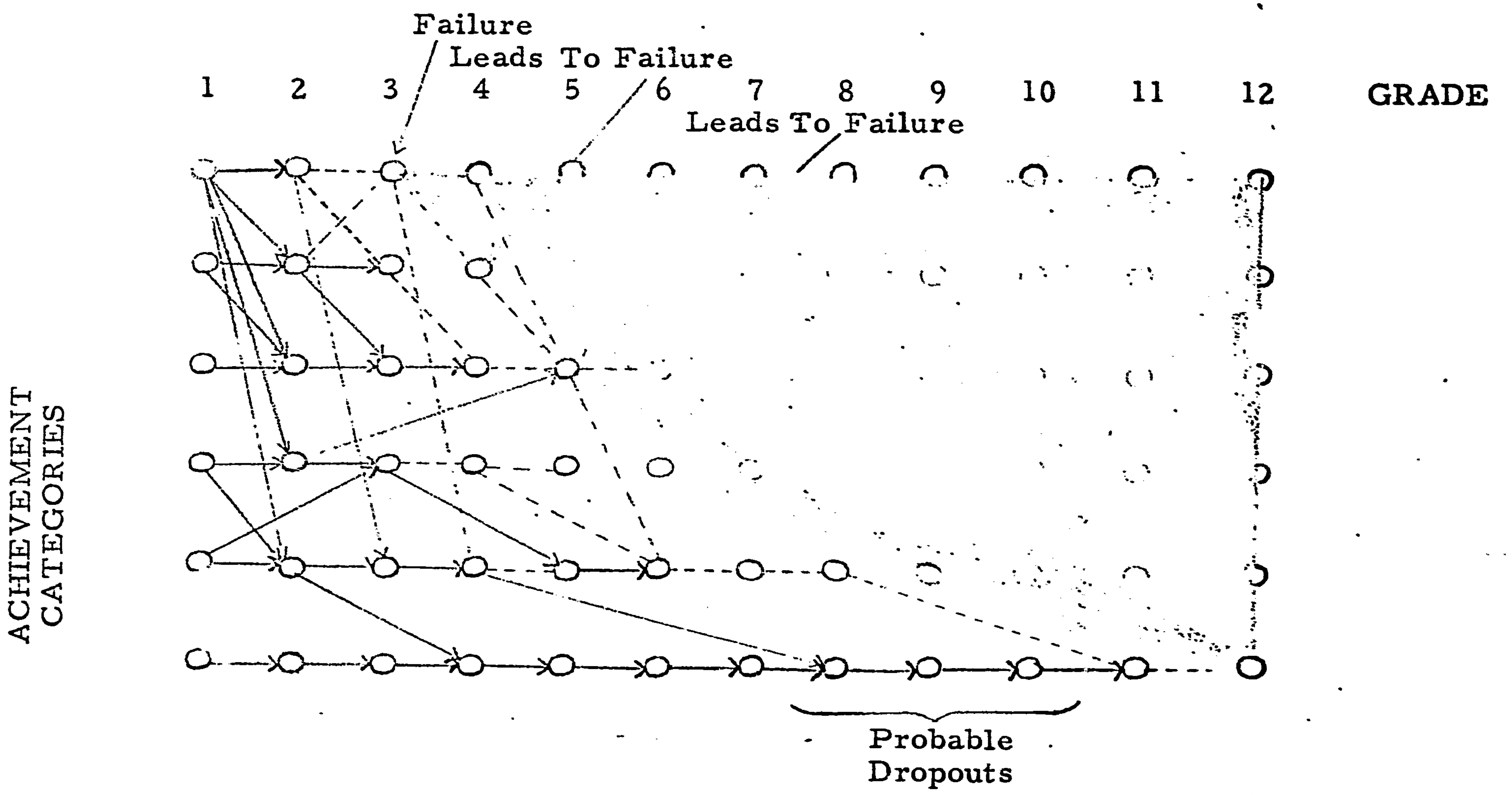
The model uses conditional probabilities to predict the achievement pattern in a given grade from the achievement pattern in the previous grade. The probabilities are of the form: "Given that a student in the fourth grade passed English, social studies, and science, and failed mathematics, the probability that he will pass English, social studies, science and mathematics in the fifth grade is 0.40." These probabilities are defined for each grade-to-grade transition, and for all combinations of subject passes and failures in each grade, and all combinations of passes and failures in the following grade. The number of students passing any combination of subjects in the following grade is predicted from 1) the transitional probabilities for the preceding grade and 2) the number of students passing each combination of subjects in the current grade. Thus, one can observe the probable future consequences of early failures--shown conceptually in Fig. 1.

The School Flow Submodel accepts the immediate achievement changes in a target student population resulting from an education improvement program, and propagates these "local" changes ahead in time to dropout, or to course-of-study selection and graduation. It thus converts short-term student achievement changes into long-range forecasts of changes in achievement and number of dropouts and the number and quality of graduates.

Individual subject-grade failure interdependencies in the curriculum matrix, such as the probability of a student failing third-grade science if he

Fig. 1

THE SHADOW CAST BY AN EARLY GAP
(of non-achievement) (in achievement)



has failed second-grade reading for example, have been derived from several hundred student records of multiple failures. In a significant percentage of the cases examined, failures (achievement gaps) "spread" from one or a few subjects to additional subjects downstream. We reproduce this indicative relationship in the School Flow Submodel to propagate the effects of early failures, and correspondingly to propagate the reductions in early failures resulting from Title I improvement programs in terms of reductions in later failures, dropouts, and low achievers.

It is especially desirable to measure the change due to a Title I program in student's achievement patterns throughout their elementary and secondary school careers. The information gained from a grade-by-grade indication of potential changes in achievement levels can provide policy planners with better insight into the effects of Title I programs. It is important to know, for instance, not only that a program applied during the second grade has no residual effect remaining by high school graduation, but also that the program has only marginal effect on achievement after the fifth grade, while another program has potentially as strong an effect through the eighth grade. Grade-by-grade achievement records are also useful in estimating and predicting dropout and truancy rates. As shown in Chapters VII and VIII, these predictions rely heavily on achievement measures. Educators and analysts, because of their familiarity with grade-by-grade achievement data, should be able to make good use of the grade-by-grade achievement projections and be comfortable with information in this form.

In this chapter, we are concerned with the average student of a particular "student type". Student types may be defined differently for each community for which the model is used. Classifications may include income and ethnic background. All the students being simulated are placed in one of up to four student types. The typology is chosen to reflect the possibility of differential effects on the students as the result of the Title I program. The differential effects will be related either to the students' achievement and personal characteristics, or to their sociological backgrounds.

After students are classified into these four types, the population size of each type, and the background characteristics and achievement level of an average student of each type are determined. This determination may be made through the use of expert judgment or by statistical methods. In most school systems, it is likely that the former method will be used. For more on this subject, see Chapter V. Within each student type, we can construct achievement distributions for the students in that type. Thus, we can use average characteristics to give us an indication of the statistical properties of the achievement levels of students of each type.

It is important to describe explicitly the measurements of achievement which are used. We consider each subject to be graded independently of other subjects, although there may be high correlation between levels of achievement for different subjects. We also assume that a pass-fail threshold has been selected for each subject in each grade. The threshold may be stated in terms of a percentile score on a standardized achievement test, in terms of numerical or alphabetical grade averages, or in terms of subjective teacher judgment. With this threshold, one can classify students into pass-fail groups for each subject in each year. A measure of achievement for a type is based on the number of students in that type in each of the pass-fail combinations over all subjects. For example, if only two subjects are considered, mathematics and English, then achievement is described by the set of four numbers indicating the number of students who pass both subjects, those who pass mathematics and fail English, those who pass English and fail mathematics, and those who pass neither. It is also possible to compute the expected number and standard deviation of subjects passed.

The projections of achievement from the current year to the following year depend on the achievement during the current year. We compute the probability of passing some subjects and failing others in the next grade, given a particular pass-fail combination in the current grade. For example, consider the two-subject case just described. We compute the probability of passing both subjects in the next grade, given that both are passed in the current grade, the probability of passing only English in the next grade, given that both are passed in the current grade, etc.

These probabilities are multiplied by the number of students passing each combination of subjects in the current grade to give the number of students passing a given combination in the next grade. For example, the number of people passing mathematics and English in grade 4 is equal to the number passing both in grade 3, multiplied by the probability of passing both subjects in grade 4, given that both were passed in grade 3, plus the number of people passing only mathematics in grade 3, multiplied by the probability of passing both in grade 4, given that only mathematics was passed in grade 3, etc.

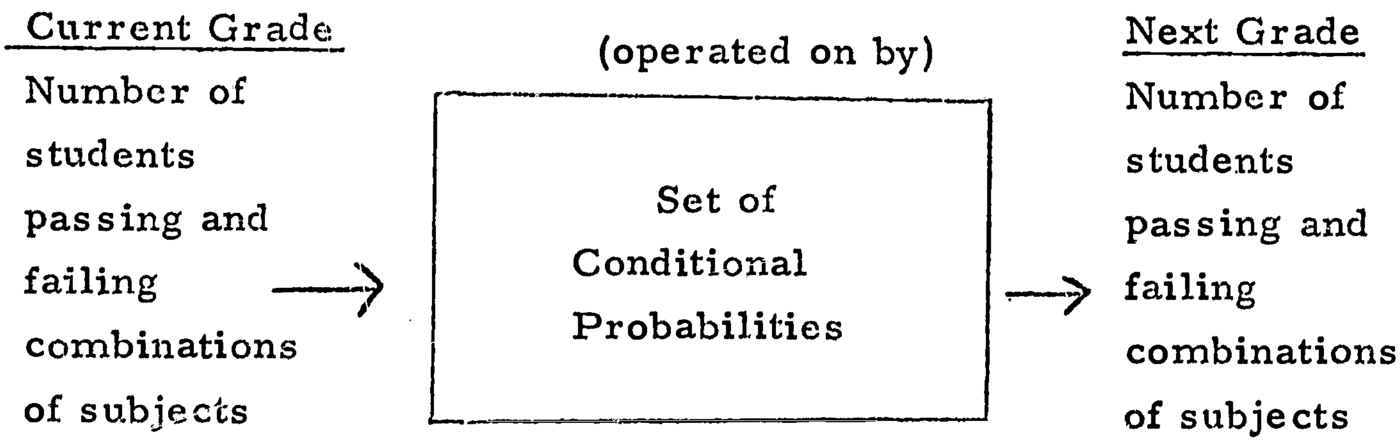


Figure 2

A change in achievement in the current grade due to a Title I program is assumed not to affect the probability that a student, having passed and failed combinations of subjects in the current grade, will pass and fail a combination in the following grade.

The set of subjects which a student will pass in the following grade is dependent only on the set of subjects passed in the current grade. The effect of an increase (or decrease) in the average number of subjects passed by his peers is not considered.

Based on the above measures and assumptions, a recursive scheme for projecting achievement has been adopted. The number of students passing each combination of subjects for each grade is computed from school records, as is the set of probabilities at each grade specifying the relationships between subjects passed in the previous grade and subjects passed in the current grade. The numbers of students passing each combination of subjects in the grade at which the Title I program is to be applied is determined from the student distribution before Title I and evaluation of the Title I program in terms of its effects while present in the school. This new set of proportions is then combined with the set of probabilities, specifying the relationships of subjects passed between grades, and new numbers of students passing each combination of subjects are determined, starting from the grade at which the Title I program was applied and working up to graduation. At each grade, the expected number of subjects passed, and its standard deviation can be computed.

Once data are gathered on the conditional probabilities of the average student's passing a certain combination of subjects in a given grade (given that he passed a fixed combination of subjects in the previous grade), this information can be used to project achievement in each grade of any set of students, actual or simulated, whose performance in the previous grade is known.

Description of a mathematical projection method like the one presented here is only a first step towards implementation. Parameters used in the procedure must be estimated from available data and the assumptions underlying the model must be validated before it can be used for actual projections as inputs to decision-making.

Estimation of the parameters involves estimation of the conditional probabilities of passing a set of subjects in grade t, given that a set of pre-requisite subjects were passed in grade t-1. The common sense estimate is the ratio of the number of students who, having passed the set of pre-requisite subjects in grade t-1, passed the desired set of subjects in grade t, to the total number of students in grade t-1. This estimate is shown in Note 1 to have certain desirable statistical properties. Certain tests can be made from the estimates: a test that the conditional probabilities are the same for each grade, and a test that the conditional probabilities are equal to specified constants. The results of these tests are described in Note 3.

In many schools, data may be incomplete or non-existent. The common sense estimates described above are not useful in this case, because many or all of the ratios are zero. Even if provision for additional data gathering is made, some time elapses between the commencement of a data gathering effort and its completion. In order to implement the model before and during the data-gathering efforts, estimates are required which combine whatever data is available with a priori knowledge. The Bayesian estimation procedure described in Note 2 defines an estimate which combines a priori, subjective evaluation of the conditional probabilities with whatever data is available. As more data become available, they can be incorporated into the estimates, with a very large sample of data, the initial subjective evaluations play an almost negligible role in determining the estimates.

One of the most important assumptions underlying the procedures described in this chapter is that only the achievement record of the current year is necessary to predict achievement in the next year. An experiment to validate this assumption is described in detail in Note 3. The results, although based on too small a sample to be conclusive, are encouraging, i.e., assumption seems justified. It is expected that further validation of this assumption will be attempted before the procedure is fully implemented.

In order to describe the approach discussed here in quantitative terms, it is helpful to present a brief introduction to the theory of Markov chains. Markov chains, by virtue of their simplicity and flexibility, play an important role in applications of probabilistic processes in many areas. A good introduction to Markov chain theory is found in Kemeny and Snell (3). The principal relevant elements of the subject are summarized here. Consider a quantity which takes on one of a finite set of values at a point in time, t; its value may change at fixed discrete points in time, t, t+1, . . . These values may be descriptive, or they may be quantitative. For example, assume that the brand of soap purchased by a consumer is the variable of interest. Assume further that the consumer purchases one bar of soap every week, and that there are M brands available. The variable "bar of soap brand name" takes on integer values from 1 to M, according to the brand purchased, for each week. Purchasing a bar of the i^{th} brand of soap is equivalent to state i, written s_i. There are, at each week t, states $s_1, s_2, s_3, \ldots, s_m$ which are then possible.

The central assumption of Markov chain theory states that, to determine the probabilities of the various states at time t, given the states at the previous weeks t-1, t-2, etc., only the state of the previous week (t-1) must be studied. According to the Markov Assumption, information about the states in earlier weeks does not change the conditional probability of moving from a state at time t-1 to a state at time t. In order to formalize this assumption, let $p_t(s_i)$ be the probability of the random variable's being in state s_i at time t. In the example discussed, $p_t(s_i)$ is the probability that a consumer buys a bar of Brand i soap during the t^{th} week. This probability can be loosely interpreted as the fraction of all consumers who buy Brand i soap during the t^{th} week.

The conditional probability $P(s_j s_i, t)$ is defined as the probability that the random variable is in state s_j at time t, given that it was in state s_i at time t-1. By the laws of conditional probability,

$$P(s_j s_i, t) = \frac{P(s_j \text{ at t and } s_i \text{ at t-1})}{P(s_j \text{ at t-1})}$$

The conditional probability equals the ratio of the joint probability of being in state s_j at time t and in state s_i at time t-1 to the probability of being in state s_i at time t-1. In terms of the example, the conditional probability can be interpreted as the proportion of consumers who, having bought Brand i during the $(t-1)^{th}$ week, buy Brand j during the t^{th} week. This proportion is numerically equal to the ratio of the number of persons who bought Brand i during the $(t-1)^{th}$ week and who bought Brand j during the t^{th} week.

Using the laws of conditional probability, one can show that

$$P_t(s_j) = \sum_{i=1}^{M} P(s_j s_i, t)\ P_{t-1}(s_i), \quad \text{for } j=1, \ldots, M$$

or, in matrix notation,

$$P_t = P_t\, p_{t-1}.$$

This equation can be used recursively to show that

$$P_{t+1} = P_{t=1}\, p_t = P_{t=1}\, P_t\, p_{t-1},$$

etc., so that

$$P_{t+k} = P_{t+k} P_{t+k-1} \cdot \cdot \cdot \cdot P_t P_{t-1} \cdot$$

The key assumption underlying the Markov model is that the conditional transition probabilities $P(s_j s_i, t)$ are independent of the probabilities of state at time t-2. This assumption may be written:

$$P(s_j \text{ at } t \ \ s_i \text{ at } t\text{-}1,\ s_k \text{ at } t\text{-}2, \ldots = P(s_j \text{ at } t,\ s_i \text{ at } t\text{-}1)$$

$$= P\ (s_j,\ s_i,\ t).$$

Validation of this assumption is crucial to a correct application of Markov chain theory.

It is also important to note that, while the Markov property may hold for the M states as they are defined, it does not generally hold for a subset or combination of the M sets into $M' < M$ states. Hence, the assumption above must be verified for each definition of states studied, even if only two states are combined or one is deleted.

Markov models in educational modeling have been used extensively, both for individual student models and for aggregate models. For a discussion of the former, see Bush and Mosteller (2). Markov chain theory is used here to define the recursive projections of achievement.

For a given school, divided into T grade classifications, and offering r subjects, there are assumed to be pass-fail thresholds for each subject. A student takes all of the r subjects in each grade classification 1 through T, and receives a pass or fail grade, receiving $r \cdot T$ grades in all. His academic status at the end of the t^{th} grade can be expressed in terms of a state s_i where i is a binary number of r digits, and a "one" indicates pass in the subject corresponding to the place of the one in the binary number. If, for example, r=3, and the student passed the first and third subjects, then he would be in state s^t_{101}. The possible states for this example are s^t_{111}, s^t_{110}, s^t_{101}, s^t_{011}, s^t_{100}, s^t_{010}, s^t_{001}, s^t_{000}.

It is clear that there are in general, 2^r states. If two thresholds, implying three classifications, good, pass, and fail, were used, then the states could be defined similarly, and there would be 3^r states. If we assume that the Markov assumption holds, i.e., that academic performance in grade t depends only on that of grade t-1, and not directly on anything earlier, then a matrix can be defined to predict educational performance.

Suppose that the student has a certain probability of passing each of the r subjects which is set as an initial condition, i.e., $P(s^{o}_{ijk\ldots m}P(s_i))$ for all of the 2^r states. This probability is written as $p^{o}_{ijk\ldots m}$, p_i, and the vector of probabilities corresponding to the 2^r states as P_o. If the conditional probability state vector at time t could be constructed directly by the relation,

$$p_t = P_t \, p_{t-1} \,,$$

where P_t is a matrix whose elements are the conditional probabilities described. Specifically if s_i^{t-1} is a state at grade t-1 whose subscript index represents a binary number, with ones corresponding to subjects passed, and s_j^t is a state at grade t whose binary subscript also indicates a configuration of passed subjects, then $p_{ij}(t)$ is an element of P_t defined as:

$$P_{ij}(t) = \text{Prob}\ (s_j^t \quad s_i^{t-1}\ ).$$

By applying this relation repeatedly, we may write p_t in terms of the transition matrices and the initial conditions as:

$$p_t = P_t P_{t-1} \ldots P_1 p_o.$$

If the product of transition matrices

$$P_t^* = \prod_{j=1}^{t} P_j$$

is computed, then different initial conditions can be used to determine the final state probabilities. Alternatively, if the final state probability vector is known, then initial conditions can be calculated, using a matrix inverse (if it exists), as

$$p_o = (P_t^*)^{-1} \, p_t,$$

and different end conditions can be studied in terms of their effect on the initial probability state vector. If the Markov chain is stationary, then $P_{ij}(t) = p_{ij}$ for all $t=1 \ldots, T$, and $P_T^* = P^T$, the T^{th} power of the one-step transition matrix.

Example: Suppose, in grade 2, only mathematics and English are offered. Suppose, out of 50 students, 10 pass both, 20 pass only English, 10 pass only mathematics, and 10 fail both. Suppose that the conditional transition matrix is, with M standing for "pass math" and E symbolizing "pass English,"

		ME	E	M	NONE (grade 3)
(grade 2)	ME	.6	.2	.2	0
	E	.2	.4	.2	.2
	M	.2	.2	.4	.2
	NONE	0	.2	.2	.6

and it is desired to predict the achievement at grade 3. The solution is given by:

$$\begin{Vmatrix} .6 & .2 & .2 & 0 \\ .2 & .4 & .2 & .2 \\ .2 & .2 & .4 & .2 \\ 0 & .2 & .2 & .6 \end{Vmatrix} \times \begin{Vmatrix} 10 \\ 20 \\ 10 \\ 10 \end{Vmatrix} = \begin{Vmatrix} 12 \\ 14 \\ 12 \\ 12 \end{Vmatrix}$$

so that 12 pass both subjects in grade 3; 14 pass English only; 12 pass math only, and 12 pass neither.

The state probabilities at each grade can be used to compute the average and standard deviation of the number of subjects passed, which give some idea of the effect of Title I programs on the base-line achievement.

Each of the 2^r states has a binary number of r digits associated with it. Let the function Z(i) be the sum of the digits of the binary number i. For example, if i=101, Z(i)=2. The average number of subjects passed per student in grade t can then be computed as:

$$\overline{Z} = \text{average subjects passed}_t = \sum_{i=1}^{2^r} p_t(s_i)\, Z(i).$$

The amount of grade advancement can be defined as the ratio of the average number of subjects passed to r, the number of subjects offered, and expected achievement at grade t can be defined by the recursive relation:

$$\overline{A}_t = \overline{A}_{t-1} + \sum_{i=1}^{2^r} p_t(s_i)z(i)/r$$

The standard deviation of the number of subjects passed is given by

$$\sigma_z = \sqrt{\sum_{i=1}^{2^r} p_t(s_i)\,[Z(i) - \overline{Z}]^2} \quad ,$$

and this number is the standard deviation of grade achievement at grade t, conditional on the achievement at grade t-1. It will be assumed that the distribution of achievement at grade t is normal, with parameters as shown, conditional on the achievement at grade t-1.

Note 1. Classical Inferences for Markov Chains

In this note, estimation of the necessary parameters, the elements of the transition matrices P_t, is discussed. The classical statistical technique of maximum likelihood estimation is described, computational formulae are presented, and tests of hypotheses are given. Most of the work concerning maximum likelihood estimation and hypothesis testing is presented by Anderson and Goodman (1). A good introduction to these topics is presented in Mood and Graybill (4).

Most school districts have large numbers of grade histories extending over the period [1, T]. Any one student is represented over the T grade periods by a vector of states $(s_i^1, s_j^2, \ldots, s_k^T)$, where i, j, and k are binary numbers representing a pass-fail configuration. By sampling the records of the school, it is possible to estimate $p_{ij}(t)$, the elements of the transition matrix used to find p_t. The maximum likelihood estimate of $p_{ij}(t)$ is

$$\hat{P}_{ij}(t) = n_{ij}(t) \Big/ \sum_{k=1}^{2^r} n_{ik}(t).$$

The numerator is the total number of students sampled who, given that they were in s_i^{t-1}, are in s_j^t, and the denominator is a normalizing factor. It can be seen that

$$\sum_{j=1}^{2^r} \hat{P}_{ij}(t) = 1.$$

For large samples, the elements of $\hat{P}(t)$, $\hat{P}_{ij}(t)$, are multivariate normally distributed with mean $p_{ij}(t)$, variance =

$$p_{ij}(t)\,(1-p_{ij}(t)) \Big/ \sum_{j=1}^{2^r} n_{ij},$$

and covariance between

$$P_{ij}(t) \text{ and } P_{gh}(t) = -p_{ij}(t)\, p_{gh}(t) \Big/ \sum_{j=1}^{2^r} n_{ij}, \quad \text{if}$$

i=g and 0 otherwise.

These results hold, conditional on the sample at time t-1. A further result which can be deduced from the above for large samples concerns the elements of the vector $\hat{p}_t$, $\hat{p}_t(s_i)$. By the laws of conditional probability, we can estimate

$$\hat{p}_t(s_i) = \sum_{j=1}^{2} p_{ji}(t)p_{t-1}(s_j).$$

The distribution of $p_t(s_i)$, conditional on the sample at time t-1, is normal with mean

$$\sum_{j=1}^{2^r} p_{ji}(t)\, p_{t-1}(s_j)$$

and variance

$$\sum_{j=1}^{2^r} \left\{ p_{ji}(t) \quad (1-p_{ji}(t)) / \sum_{j=1}^{2^r} n_{ji}(t) \right\} \; p^2_{t-1} \quad (s_j)$$

An upper bound to the variance is

$$1 / \left(4 \sum_{j=1}^{2^r} n_{ji}(t) \right),$$

which is obtained by noting that the maximum of

$$\sum_{j=1}^{2^r} p^2_{t-1} \quad (s_j)$$

occurs when $p^2_{t-1} \; (s_j)$

is equal to 1 for one value of j and zero for all others.

Certain hypotheses also can be tested. The first of interest is that the transition matrices are all the same for differing values of t. Testing this hypothesis is equivalent to testing the Markov process for stationarity. The likelihood ratio test of size $1 - \alpha$ is useful here, and rejects the null hypothesis that the Markov process is stationary if

$$-2 \log_e \lambda \geq \chi(\alpha)_{(T-1)\, 2^r(2^r-1)}.$$

The quantity λ is defined as

$$\lambda = \prod_{t=1}^{T} \prod_{i=1}^{2^r} \prod_{j=1}^{2^r} \left[\frac{\hat{p}_{ij}}{\hat{p}_{ij}(t)} \right]^{n_{ij}(t)} ,$$

so that

$$-2 \log_e \lambda = -2 \sum_{t=1}^{T} \sum_{i=1}^{2^r} \sum_{j=1}^{2^r} n_{ij}(t) \left\{ \log \hat{p}_{ij} - \log \hat{p}_{ij}(t) \right\} ,$$

and $\chi(\alpha)_{(T-1)2^r(2^r-1)}$ is the 100 $(1-\alpha)$% point of the χ^2 distribution with (T-1) 2 (2 -1) degrees of freedom. The quantity p_{ij} can be calculated like $\hat{p}_{ij}(t)$ if

$$n_{ij} = \sum_{t=1}^{T} n_{ij}(t).$$

Another useful test is that of the hypothesis that the estimated Markov transition matrix is equal, row by row, to a specified set of probabilities: $\hat{p}_{ij}(t) = p^o_{ij}$, all $j=1, \ldots, 2^r$ and i fixed. The chi-squared test is appropriate here, for large samples, and the hypothesis of equality is rejected with probability of Type I error α if

$$\theta_{t,i} = \sum_{j=1}^{2^r} \sum_{j=1}^{2r} n_{ij}(t) \frac{\left(\hat{p}_{ij}(t) - p^o_{ij} \right)^2}{p^o_{ij}}$$

is greater than the chi-squared 100 α% point with 2^r-1 degrees of freedom. By convention, elements $p^o_{ij} = 0$ are not permitted.

Note 2. Bayesian Estimation for Markov Chains

In educational statistics, paucity of data always represents a problem. For example, if r subjects are considered, then each of the T transition matrices contain 2^{2r} elements, each of which must be estimated. This number is computed for a few values of r:

r	1	2	3	4	5	6
2^2	4	16	64	256	1024	4096

Even if, for r =4, 256 observations were available, there is no guarantee that each element of the matrix will be estimable from the data, i. e., will contain at least one sample observation.

Bayesian statistics allows the use of subjective evaluations to set all of the initial values of the elements of the transition matrices judgmentally. As data become available, they are used to modify the estimates of the elements of the transition matrix until, finally, the data totally determine the estimate and the effect of prior judgment vanishes. The following paragraph develops the required theory with some rigor and then the results and their use are stated.

Assume that a set of random variables x_i have an a priori m-variate Dirichlet distribution. This distribution is defined in Wilks (5). The joint prior probability distribution of the x_i is, over the simplex $0 \leq x_i \leq 1$, $i=1, \ldots, m$,

$$f(x_1, \ldots, x_m) = \frac{\left(\sum_{i=1}^{m+1} c_i - 1\right)!}{(c_1-1)!\,(c_2-1)!\,\ldots\,(c_{m+1}-1)!}\, x_1^{c_1-1} \ldots x_m^{c_m-1}\left(1-\sum_{i=1}^{m} x_i\right)^{(c_{m+1}-1)}$$

with the expectation of x_i equal to $c_i \,/ \sum_{j=1}^{m+1} c_j$, and the variance of x_i equal to

$$c_i\,(c_1 + \ldots + c_{m+1} - c_i) \,/ \left(\sum_{g=1}^{m+1} c_i\right)^2 \left(\sum_{j=1}^{m+1} c_i + 1\right)^2 .$$

Higher order and mixed moments can also be determined. The parameters c_i are assumed to be positive integers for our application of this distribution. It can also be shown that the sum $z=x_1 + \ldots + x_m$ has a Beta distribution with parameters $c_1+\ldots+c_m$, c_{m+1}, and hence $E(z) = \dfrac{\sum_{c=1}^{m} c_i}{\sum_{i=1}^{m+1} c_i}$.

If a sample of n is drawn, and y_j falls into the j^{th} out of m+1 categories, then the likelihood of the sample is

$$L(y_1,\ldots,y_m,x_1,\ldots,x_m) = \frac{n!}{\prod_{j=1}^{m} (y_j)!} \prod_{j=1}^{m} x_j^{y_j} \cdot \frac{1}{\left(n-\sum_{d=1}^{m} y_j\right)!} \left(1-\sum_{j=1}^{m} x_j\right)^{n-\sum_{j=1}^{m} y_j},$$

conditional on the sample observed. By standard use of Bayes' theorem, the posterior distribution of the x_i is proportional to the product of the likelihood and the prior distribution, or $f'(x_1,\ldots,x_m y_1,\ldots,y_m) =$

$$K' \prod_{j=1}^{m} x_j^{c_j+y_{j-1}} \left(1-\sum_{j=1}^{m} x_j\right)^{c_{m+1}+n-\sum_{j=1}^{m} y_{j-1}}$$

where K' is a constant not depending on x_i. If the decision -theoretic loss in estimating x_i is quadratic, i.e. if an increase in error causes an increase in the square of the loss, then the optimal (minimum expected loss) estimate of x_i is the mean of the posterior distribution. Hence, x_j is best estimated by $(c_j + y_j) \Big/ \left(\sum_{j=1}^{m+1} c_j + n\right)$.

The work of the previous paragraph can be applied to estimating the rows of a Markov transition matrix as follows. Estimate the entry $p_{ij}(t)$ subjectively as

$$c_j \Big/ \sum_{j=1}^{2^r} c_j, \qquad \text{for all } j=1,\ldots,2^r.$$

Take a sample of data to determine the number in state j at time t given that they were in state i at time t-1. After gathering the data, estimate the entry

$$p_{ij}(t) \text{ as } \left(c_j = n_{ij}(t)\right) \Big/ \left(\sum_{j=1}^{2^r} c_j + \sum_{j=1}^{2^r} n_{ij}(t)\right).$$

Under the assumptions of the previous paragraph, the standard deviation of the new estimate of $p_{ij}(t)$ is the square root of

$$\left(c_j + n_{ij}(t)\right) \sum_{k=1}^{2^r} \left(c_k + n_{ik}(t)\right) \Bigg/ \left(\sum_{k=1}^{2^r} \left(c_k + n_{ik}(t)\right)\right)^2 \left(\sum_{k=1}^{2^r} \left(c_k + n_{ik}(t)\right) + 1\right)^2 .$$

It can be seen that, as the sample size increases, the effect of the prior specification diminishes. Using these expressions, one can estimate parameters as data becomes available. The advantage of the Bayesian procedure is that a scarcity of data does not necessarily imply an estimated matrix with many zero elements. For small amounts of data, however, prior judgments are very important. The procedure described is conditional on the sample at time t-1.

One problem remaining is the determination of the c_i. If the c_i are all taken to be zero, then the adaptive estimate is equivalent to the maximum likelihood estimate described earlier. In the more general case, the a priori estimates for the conditional probabilities $p_{ij}^{(t)}$ can be specified by an expert on education who has experience with the school in question. By asking the question, "To what size sample do you feel your judgment is equivalent," one can set the value of $\sum_{j=1}^{2^r} c_j$. Each of the individual c_j can be determined as $c_j = p_{ij}^{(t)} \sum_{j=1}^{2} c_j$.

While the adaptive estimation procedure here is useful in dealing with skimpy data, there is much statistical work to be done in validation of assumptions, choice of loss functions, etc., in Bayesian analysis of Markov chains. It is felt that this topic is a fruitful one for further research.

Note 3. Validation of the Markov Assumptions

The assumptions of the Markov model were outlined earlier in detail. These assumptions must be validated before the model can be applied to actual data. For validation purposes, a population of more than two hundred low achievement children from a suburban New England school were studied. This population represented all of the approximately 2500 students in attendance in the high school who were poor performers and who had long records extending back through elementary school.

For a given set of pass-fail states, the Markov assumption states that

$$P_{t+1} = P_t \, p_t = P_t \, P_{t-1} \, p_{t-1}.$$

Writing the matrix with elements p(s_j at t+1 (s_i at t-1) as R^2_{t-1}, we expect, if the Markov property holds,

$$P_{t+1} = R^2_{t-1} \, p_{t-1} = P_t \, P_{t-1} \, p_{t-1},$$

and

$$R^2_{t-1} = P_t \, P_{t-1} \, .$$

Similarly, if the Markov property holds,

$$R^k_{t-1} = \prod_{j=0}^{k-1} P_{t-1+j} \, .$$

By estimating the left and right hand sides of these relationships from data and comparing them, one can test the validity of the Markov assumption. It is expected that there is to be sampling fluctuation in the elements of both sides, so that any comparison and interpretation must be considered in light of the sampling variances.

Selecting multiple samples from a small finite population implies that there is overlap, i.e., that some observations occur in more than one sample. If f is the sampling percentage, the ratio of the sampling size to the population size, then

$$\sum_{i=0}^{j} \binom{m}{i} f^{i} (1-f)^{m-i}$$

is the expected proportion of people in j or fewer samples out of m samples drawn. A table of this number, for selected values of m and f, for j=1, is shown below.

Expected % of Observations Common to One or Fewer of m samples, with each sample an 100f% sample

f \ m	3	4	5	7	10
0.25			63		23
0.32			52	22	
0.50	50	31	18		1
0.75			2		

It was decided to effect a trade-off between sampling variance due to small samples, and high correlation between samples by choosing f = 0.40, a forty per cent sample. Due to missing data, etc., the actual sampling percentage used was one or two percent smaller.

From the characteristics of the data available, it was decided further to stratify the data by sex and by drop-out vs. graduate. A set of sampling experiments or comparisons were carried out to check the Markov hypotheses. These comparisons were:

$$\left.\begin{array}{lcl} R_4^2\, P_4 & \text{compared with} & P_6\, R_3^2 \\ P_6\, P_5 & \text{compared with} & R_4^2 \\ P_5\, P_4 & \text{compared with} & R_3^2 \end{array}\right\}.$$

The first comparison measures two matrices describing transitions from the third grade to the sixth grade. The first of the two matrices is the product of the matrix describing direct, conditional probabilities of sixth grade states, conditional on fourth grade states, and the transition matrix from third to fourth, compared with the direct transition matrix from third to fourth, compared with the direct transition from third to fifth, multiplied by the transition matrix from fifth grade to sixth. The other comparisons follow analogously. Grades three through six were chosen because the data for those grades was most complete.

There are five distinct matrices in the three above comparisons. Each was estimated from a separate 40% sample, and the samples were all matched for the stratifying categories; i.e., each sample contained 40% of the number in each of the four population subcategories.

The standard errors of the elements of the matrices, obtained from a small finite population, explain some of the observed variation between the two sets of matrices. If the Markov property is true, and if both sides of the above are post-multiplied by the p_{t-1} vector, where t corresponds to the subscript on the P matrices on the left-hand side, and t-1 corresponds to the subscript on the R matrices of the right-hand side, the final state vectors can be compared. In other words,

$$R_4^2 P_4 p_3 = p_6 \qquad \text{compared with} \qquad p_6 = P_6 R_3^2 p_3$$

$$P_6 P_5 p_4 = p_6 \qquad \text{compared with} \qquad p_6 = R_4^2 p_4$$

$$P_5 P_4 p_3 = p_5 \qquad \text{compared with} \qquad p_5 = R_3^2 p_3$$

and only state-vectors need be compared. Tests such as the X^2 test and t-tests generally used to make paired comparisons of this sort are only approximately valid here. The correlation between state vectors calculated by this procedure has not been worked out, although it most probably, judging by the above table of expected overlap between samples, is positive.

The first set of analyses considered four subjects, mathematics (M), spelling (P), writing (W), and reading (R), each with a pass-fail threshold. This analysis considers, therefore, 16 states. Inclusion of one of the letters implies pass, exclusion implies fail; NON denotes failure of all subjects. The three comparisons noted above are presented in Analyses 1-3. It should be remembered that the base vector is based on the actual records available for the population in grade 6, but the computed vectors are based on the total population in grade 3, a number generally smaller. This explains the disparity of the total of the base vector vs. that of the computed vectors. In order to compare the computed vectors with the base vector, the quantities shown must be normalized by dividing by the totals shown under the headings. Small disparities between the totals of the base vector columns for different analyses, and between the computed vectors are due to round off to preserve integer values. A procedure to reduce these disparities has been implemented in later analyses.

It can be seen from these tables that the two most heavily occupied states, the states of passing everything and failing everything, are almost identical for the two computed vectors, indicating that the Markov property does hold for the four subjects considered over grades 3 - 6.

Even though there is less of a percentage agreement between some of the other states as computed by the two procedures, it appears as though the Markov model provides a reasonable approximation to the situation studied.

As was pointed out earlier, the Markov property does not necessarily hold for a combination or elimination of certain states. Two studies were made to study this property, one combining the states writing and spelling into a new state (E), the other deleting spelling entirely. The comparison of the computed vectors is shown in Analyses 4 and 5 for the first comparison only in each case. It can be seen from these tables that, while the Markov property seems to hold as before, the agreement between the computed vectors is not quite as great as before. Care must indeed be taken in collapsing or deleting states in a Markov chain.

A conservative upper bound for the standard deviation of the difference between elements of the two computed vectors is

$$\text{S. E. (computed vector}_1\text{element}_i \text{ - computed vector}_2\text{element}_i)$$

$$\sqrt{\frac{1}{2 \cdot \text{TOTAL in smaller of computed vector columns}}}$$

which can be derived as follows.

If m_{1i} and m_{2i} are the elements in question, then $p_{1i} = \frac{m_{ij}}{\text{TOTAL}}$ and $p_{2i} = \frac{m_{2i}}{\text{TOTAL}}$ have variance $\leq \frac{1}{4\ \text{TOTAL}}$, where TOTAL is the total in the smaller of the two columns.

$$\text{Hence, } \frac{\text{var}(m_{1i} - m_{2i})}{\text{TOTAL}} \leq \frac{1}{2\ \text{TOTAL}} - \frac{2\ \text{cov}\,(m_{1i}, m_{2i})}{\text{TOTAL}} .$$

The correlation between samples implies that the covariance is positive, and hence 1/2 TOTAL is an upper bound to the variance. Because TOTAL $\approx$ 200, the bound for the standard error is about .05 for each element of the difference between the computed vectors.

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ANALYSIS NUMBER 1

COMPARISON OF STATE VECTORS FOR GRADE 6

VECTOR 1 = BASE VECTOR GRADE 3 X PROBABILITY OF TRANSITION GRADE 3 TO 4
X PROBABILITY OF TRANSITION GRADE 4 TO 6

VECTOR 2 = BASE VECTOR GRADE 3 X PROBABILITY OF TRANSITION GRADE 3 TO 5
X PROBABILITY OF TRANSITION GRADE 5 TO 6

STATE	BASE VECTOR GRADE 6 (251)	COMPUTED VECTORS 1 (188)	COMPUTED VECTORS 2 (203)
MPWR	86	71	72
MPW	11	11	11
MP R	6	4	8
M WR	7	8	4
PWR	16	20	3
MP	6	2	5
M W	6	11	4
M R	4	1	5
PW	11	7	8
P R	7	1	3
WR	5	2	1
M	12	7	11
P	9	2	3
W	7	0	6
R	6	0	12
[illegible]	[illegible]	41	47

ANALYSIS NUMBER 2

COMPARISON OF STATE VECTORS FOR GRADE 6

VECTOR 1 = BASE VECTOR GRADE 4 X PROBABILITY OF TRANSITION GRADE 4 TO 5
X PROBABILITY OF TRANSITION GRADE 5 TO 6

VECTOR 2 = BASE VECTOR GRADE 4 X PROBABILITY OF TRANSITION GRADE 4 TO 6

STATE	BASE VECTOR GRADE 6 (251)	COMPUTED VECTORS 1 (233)	COMPUTED VECTORS 2 (234)
MPWR	86	85	85
MPW	11	7	16
MP R	6	11	7
M WR	7	10	10
PWR	16	5	18
MP	6	4	4
M W	6	12	8
M R	4	5	2
PW	11	9	9
P R	7	3	2
WR	5	3	4
M	12	12	15
P	9	3	2
W	7	4	0
R	6	11	0
NON	52	49	52

ANALYSIS NUMBER 3

COMPARISCN OF STATE VECTORS FOR GRADE 5

ECTOR 1 = BASE VECTOR GRADE 3 X PROBABILITY OF TRANSITION GRADE 3 TO 4
X PROBABILITY OF TRANSITION GRADE 4 TO 5

ECTOR 2 = BASE VECTOR GRADE 3 X PROBABILITY OF TRANSITION GRADE 3 TO 5

STATE	BASE VECTOR GRADE 5 (750)	COMPUTED VECTORS 1 (191)	COMPUTED VECTORS 2 (209)
MPWR	89	67	75
MPW	14	7	22
MP R	4	2	2
M WR	7	3	3
PWR	13	9	5
MP	6	5	6
M W	8	11	2
M R	3	1	0
PW	5	1	4
P R	4	2	0
WR	8	11	6
M	7	0	0
P	6	1	8
W	8	4	9
R	5	1	8
NON	63	66	59

ANALYSIS NUMBER 1

COMPARISON OF STATE VECTORS FOR GRADE 6

(Writing and Spelling Combined into E)

VECTOR 1 = BASE VECTOR GRADE 3 X PROBABILITY OF TRANSITION GRADE 3 TO 4
X PROBABILITY OF TRANSITION GRADE 4 TO 6

VECTOR 2 = BASE VECTOR GRADE 3 X PROBABILITY OF TRANSITION GRADE 3 TO 5
X PROBABILITY OF TRANSITION GRADE 5 TO 6

STATE	BASE VECTOR GRADE 6	COMPUTED VECTORS 1	COMPUTED VECTORS 2
MER	86	69	74
ME	11	19	11
M R	17	20	15
ER	16	24	6
M	24	20	25
E	11	8	8
R	18	5	15
NON	68	47	62
TOT	251	212	216

ANALYSIS NUMBER 1

COMPARISON OF STATE VECTORS FOR GRADE 6

(Spelling Deleted)

VECTOR 1 = BASE VECTOR GRADE 3 X PROBABILITY OF TRANSITION GRADE 3 TO 4
X PROBABILITY OF TRANSITION GRADE 4 TO 6

VECTOR 2 = BASE VECTOR GRADE 3 X PROBABILITY OF TRANSITION GRADE 3 TO 5
X PROBABILITY OF TRANSITION GRADE 5 TO 6

STATE	BASE VECTOR GRADE 6	COMPUTED VECTORS 1	2
NWR	93	89	78
NW	17	25	15
N R	10	8	10
WR	21	22	8
N	18	13	19
W	18	8	14
R	13	2	14
NON	61	48	55
TOT	251	215	213

CHAPTER VII

THE DROPOUT/TRUANCY SUBMODEL

In the previous chapter, a model for forecasting changes in achievement due to Title I programs was discussed. In this chapter we measure changes in the dropout and truancy rates due to changes effected by a Title I program. For example, if a Title I program applied to the second grade causes an increase in student achievement at the end of the ninth grade, this projected change in achievement can be used to predict changes in the truancy and dropout rates during the tenth grade. Changes in dropout and truancy rates are calculated from changes in student achievement and student impedance to learning. Community factors also influence these rates, but are not affected, at least in the short run, by Title I.

The effects of a Title I program applied in a given year (immediate effects), as measured by their relevance to and impact on the students involved (see Chapter IV), can be transformed into projected changes in achievement after the Title I program has been applied. The projection of these changes is discussed in Chapter V. Not only does achievement change, however, but students' motivation for learning also changes. This change in attitude can be measured in part by the change in the number of dropouts and truants in the years following the application of a Title I program, which we relate directly to the projected change in achievement.

The projection of changes in dropout and truancy ratio is useful not only for its own sake, but also for projecting changes in educational opportunity and projected earnings in future years; these last two topics are discussed in more detail in Chapter IX.

The change in the number of dropouts and truants during a given grade is projected by a linear function of the change in achievement in that grade due to a Title I program (dropouts normally occur only in grades nine through twelve, due to the enforcement of compulsory education laws). The relationship of changes in dropouts and truants to changes in achievement is computed, based on a formula which uses evaluations by educators as well as available data.

Dropout and truancy rates for a given year can be computed either as a fraction of the students who began the given year, or as a fraction of students present at a specified fixed time in the past. These ratios will differ because of changes in the school flow population due to dropouts during students' ongoing school careers, or transfers and deaths. The first rate can be interpreted as the conditional probability of the average student's becoming a dropout or truant during a given grade, given that he began that grade; this definition is analogous to the definition of rate of mortality used in life insurance tables. The second rate measures the probability that the average student becomes a dropout or truant in a certain grade, given that he entered the school population at a certain time in the past, such as first grade. Changes in these rates due to changes in the number of dropouts and truants, as a function of a Title I program, are computed directly.

There are many factors which affect the dropout and truancy rates; these factors can generally be categorized as community factors, impedance factors (see Chapter V) and achievement factors. The community factors are measured by variables which describe the socio-economic environment in which students live; the second are described in terms of the home environment and children's attitudes toward the classroom and formal instruction, and the third are based on students' grade averages. A more specific delineation of the various factors is given after a discussion of the legal definitions of truancy and dropout and of some of the school system errors in data reporting.

Although the legal definitions of truancy and dropout vary from district to district, there are certain general principles which are consistent. Truancy can be considered as the absence from school of a child of school age without parental knowledge. Unverifiable medical excuses and absences to care for sick relatives seem to comprise a large portion of these unlawful absences. Legally, unlawful detention at home of children by parents does not constitute truancy, but the absolute numbers of unlawful absences and truants are so small that we make no distinction in this model.

Dropouts legally cannot occur before a child is eligible for working papers. Although students may be absent for extended periods before that time, they are not generally considered dropouts. The local Board of Attendance probably classifies these children as truants, and is responsible for investigating the causes of absence. After a student passes the age at which dropping out is legal, truancy rates may no longer be meaningful, and extended absences can be considered instances of dropping out.

The measurement of truancy and dropout may reflect certain systematic inaccuracies. Classroom attendance reporting or child accounting often plays an important role in a school's finding. For example, New York City schools used to receive support as a function of average daily attendance. These schools tended to remove students from the rolls who were absent, legally or illegally, and to re-enroll them upon their return. Absence rates therefore tended to be biased downwards. The large student case load pressures on Boards of Attendance is frequently further compounded by their obligation to verify children's absences and to determine their causes. Large case loads may introduce further inaccuracies into the reporting of absences and their causes.

Dropouts and truancy traditionally seem to be closely related to similar causal factors. Although these causal factors are impossible to measure on a large scale, quantitative surrogates can be found to replace them. As stated earlier, some of the causal factors commonly used to explain truancy and dropout rates relate to the classroom environment and the child's ability to participate in it, the community attitude towards education, parental background and the positive or negative impetus it provides for a good education, the quality of the education provided, the season of the year, and the student's age.

There is a quantifiable proxy variable for each of these factors. The classroom environment can be measured, at least in a rudimentary way, by the amount of space and material available for each student and by the number of students in a class. The monthly rental rate in the neighborhood provides a rough guide to the economic position of the community, and, even more roughly, a measure of its acceptance of the need for education.

Parental education, income levels, and presence/absence of the father in the home provide reasonable surrogates to define the home environment for individual students. In aggregate models, community averages can be used.

The quality of education varies from class to class within a school. This variation is reflected in an absence rate which varies markedly with class schedule within a given school. Truancy and dropout are functions of time, as well. As male students approach the age of sixteen, when generally they can legally obtain working papers, their truancy and dropout rates increase. Female students tend to be absent earlier, due more perhaps to parental pressure than to educational causes.

Other factors that determine attendance rates include the physical and mental health of a student, and the "social pathology" or abberations in the homelife.

A more extensive study of truancy can be found in a study prepared in 1949 by the Citizens Committee on Children of New York City, Inc. Much of the previous discussion is summarized from findings presented in that study. An attempt to predict dropout rate as a function of community characteristics is given by R. Dentler and M. Warschauer (1965).

Numbers of dropouts and truants for a given grade and type of student depend, as we have seen, on community factors, the child's impedance to learning, and his achievement level. Title I programs do not have an immediate effect on the community environment of the students, so that a change in the number of dropouts or truants due to Title I can be considered approximately independent of community factors. The application of a Title I program in, for example, grade 3, may change the average student's impendance to learning and his achievement. These changes will continue and be propagated to some extent throughout the student's educational career, in a way which can be measured by the projected change in student achievement for the years following application of a Title I program. A relationship between projected changes in the number of dropouts and truants after Title I application and changes in impedance and achievement at the time of the Title I program can therefore be studied in terms of the projected change in achievement following Title I.

It should be noted that measurement of impedance is a difficult task, and projecting impedance is even more difficult. Achievement data, while certainly not representing all information possible available for predicting changes in truancy and dropout, are available in almost all schools and are familiar to educators. The lack of availability of other data, more than theory, restricts us to the use of achievement data for predicting changes in truancy and dropout rates. Similar reasoning leads to the use of a linear model, rather than one with higher order terms and more parameters. If it is found that nonlinear relationships exist and can be well approximated by linear ones over certain regions, then the procedure described here for predicting changes in dropout and truancy rates can be applied.

In view of the previous paragraph, we define linear relationships between the projected change in achievement at grade k_1, written ΔA_{k-1}, and the change in the number of truants and dropouts at grade k, written Δn_k^d and Δn_k^t, respectively:

$$\Delta n_k^d \approx b_1 \Delta A_{k-1} ,$$

$$\text{and} \quad \Delta n_k^t \approx b_2 \Delta A_{k-1} .$$

The quantity ΔA_{k-1}, was defined in the previous chapter as the projected expected achievement at grade k-1 following the application of a Title I program less the expected achievement at grade k-1 if no Title I program had been implemented.

The constants b_1 and b_2 could be determined by the least squares regression procedure if a sufficient number of observations were available from different schools in communities with similar socio-economic and demographic characteristics and of comparable educational level, on both Δn_k^d, Δn_k^t, and ΔA_{k-1}. Because Title I programs are relatively new, no data are or will be available for some time. Prior judgments must be used to set the values of b_1 and b_2, and these judgments should be modified by the use of data as it becomes available.

The parameter b_1 can be determined by asking the following two questions:

(a) Given the current level of achievement in grade k-1, what is your best guess of the number of students who will drop out if their achievement is as shown but who would not drop out if their achievement were to increase one grade level at this grade?

(b) What is the range you would give around your answer in (a) so that you have 50% confidence that the actual correct number is included in the interval? (That is, your answer to (a) may not be precisely correct--what is the range in which you are 50% certain the real number will fall?)

If the answer to question (a) is written B_{11}, and the answer to (b) is written B_{12}, then a good estimate for b_1 is

$$\hat{b}_1 = - B_{11};$$

the standard deviation which the estimate is imputed to have is $B_{12}/1.36$, as shown by Mosteller (see references at the end of the chapter). As data become available, a new estimate should be calculated which utilizes the new data. For calculation of such an estimate, formulae are available in Pratt, et al. Calculations for b_2 follow in the same way.

The dropout rate during grade k can be computed, conditional on the number starting grade k, as one minus the number who enter grade k + 1, less population transfer through moves and deaths, over the number who enter grade k. If M_k is the number who enter grade k, and R_k is the number of net transfers and deaths during grade k (generally zero or very close to zero), then

$$d_k = 1 - \frac{M_{k-1} - R_k}{M_k} = \frac{M_k - M_{k+1}}{M_k} + \frac{R_k}{M_k}$$

For our purposes, R_k probably can be ignored.

An alternative definition of dropout rate during grade k is one minus the ratio of the number starting grade k + 1 to the number starting the grade at which the Title I program was applied. This definition is useful again if the net immigration, emigration and deaths are very small. If the grade at which the Title I program is applied is taken to be grade zero, then

$$D_k = 1 - \frac{M_{k+1} - R_k}{M_0} = \frac{M_0 - M_{k+1}}{M_0} + \frac{R_k}{M_0}.$$

The two definitions are related by the equation

$$d_k = \frac{D_k}{1 - \sum_{j=1}^{k-1} D_j} ,$$

which is easily verified by direct substitution.

A change in achievement of ΔA_{k-1}, in grade k-1 produces a change in the number of dropouts equal to $b_1 \Delta A_{k-1}$ during grade k, assuming negligible immigration, etc. The change in the number of students entering grade k is

$$+ \Delta n^d_{k-1} - \Delta n^d_{k-2} \ldots - \Delta n^d_0 ,$$

or, by our previous assumptions,

$$- b_{1(k-1)} \Delta A_{k-2} - b_{1(k-2)} \Delta A_{k-3} - \ldots b_1 \Delta A_0 .$$

This number can be used as the numerator in calculating D_k; because the b_1's for each grade are each negative, a positive change in achievement implies a decrease in the number of dropouts. The change in the unconditional dropout rate during grade k due to Title I program effects is

$$\Delta D_{k-1} = + \sum_{j=1}^{k-1} b_{1j} \frac{\Delta A_{j-1}}{M_0}$$

The change in the conditional dropout rate can be computed very approximately as

$$\Delta d_{k-1} \approx + b_{1(k-1)} \frac{\Delta A_{k-1}}{M_{k-1}} ,$$

if the change in the number of dropouts is small.

For example, suppose that the following data is available from school records:

Grade	9	10	11	12
Number entering grade	100	98	96	94
Average Achievement	7.4	7.2	7.2	7.0
Unconditional Dropout Rate	--	.02	.04	.06
Conditional Dropout Rate	--	.02	.02	.02

A Title I program is applied at grade 8, so that, in the following years,

Average Achievement After Title I	7.8	7.6	7.4	7.4

It is estimated that $b_1 = 0.5$ for all grades. Using the formulae just outlined, we compute

Grade	9	10	11	12
Change in Number Number Entering Grade = - Change in Dropouts	--	+ 2	+ 2	+ 1
Change in Unconditional Dropout Rate	--	-.02	-.02	-.01
Change in Conditional Dropout Rate	--	-.02	-.02	-.011

Truancy calculations can be made in analogous ways using b_2 instead of b_1.

CHAPTER VIII

THE COURSE OF STUDY SELECTION SUBMODEL

In many high schools, students have several choices of academic programs available: College, business, vocational, etc. In this chapter we define a method for determining the change in the proportion of students eligible for each of these programs due to an improvement in their academic achievement caused by a Title I program.

It is assumed that the change in the proportion of students of a given student type who choose a given course of study can be determined from the characteristics of the achievement distribution of all students of that type. The effect of a Title I program on student achievement in future years can be projected from details of its initial impact on the students (see Chapter VII). The projected achievement distribution may be different from the distribution before the application of a Title I program, and the difference can then be translated into a change in the proportions of students eligible for each course of study. Radical shifts in the achievement distribution might imply that more students can shift into a particular course of study than the school's facilities might admit. To forestall this possibility, constraints are placed on the number of students allowed to enroll in each course of study, and a constrained allocation is made.

To begin the analysis, the available courses of study are ranked in terms of the achievement levels of the students who are enrolled in them. A plausible ranking might be college preparatory, business, and vocational, in decreasing order of achievement. Using this ranking, historical student choice patterns, and the achievement distribution for students of a given type, we calculate achievement thresholds which categorize students in terms of course of study. After the Title I program has been applied, the achievement distribution for the given type of student is projected--using the results of Chapter V--to the grade at which course of study selection occurs. The new achievement distribution is then used, with the original thresholds, to determine the new proportion of students eligible for each course of study. Finally, the proportions are checked against the constraints determined by the school and adjustments are made until the proportions satisfy these constraints.

In Chapter V, the expected achievement and standard deviation of achievement for the average student were computed. We assume that achievement of all students of a given type, e. g. type defined by economic level and/or race, is distributed according to a normal (or bell-shaped distribution. The average (or mean) achievement level and the standard deviation completely specify the characteristics of the bell-shaped curve.

Schools which offer course of study selection generally allow only one final choice, often to be made as the student enters the ninth grade. Although a student's choice of electives in earlier years may point towards a particular course of study, his final selection of a given course of study is heavily dependent on his achievement, relative to the average, at the time the choice is made. Students with achievement far above average tend to elect an academic or college preparatory program; students whose achievement is less than average often select a vocational program. Although this generalization will not hold for each individual student, it appears to be true in the aggregate. We therefore assume that the courses of study which are available can be ranked, so that the first is taken primarily by the highest achievement group and so on. Inherent in this ranking is the notion that there are achievement thresholds which determine the various courses of study. If a particular student has an achievement score between two given thresholds, he is assumed to be eligible for the corresponding course of study. This concept is illustrated by the example in Figure 1.

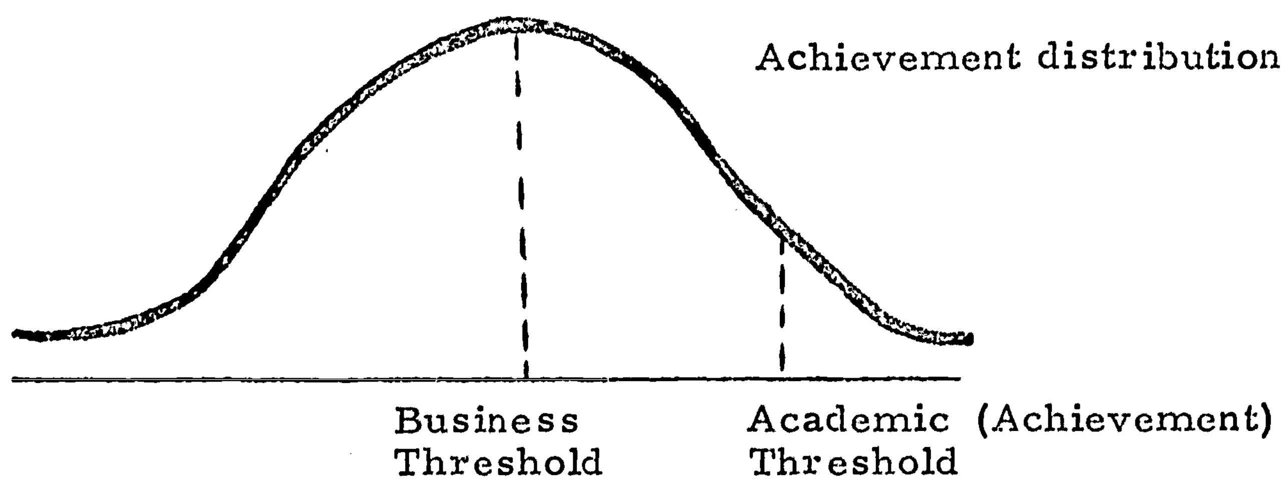


Figure 1

Again, this assumption should be approximately valid for aggregated analysis of student achievement.

In the example shown, the fraction of students whose achievement is greater than the academic threshold is assumed to choose the academic course of study; those whose achievement falls between the business threshold and the academic threshold are assumed to choose the business course of study, and so on.

The thresholds can be computed in a sequential manner. If the proportion of students of a given type enrolled in the academic course of study is taken to be the area under the achievement distribution curve to the right of the academic threshold, then the academic threshold can be determined by relating this fraction to the parameters of the distribution. One can then equate the area under the curve between the business threshold and the (known) academic threshold with the proportion of students of the given type enrolled in the business course, and solve for the business threshold. The process continues until all thresholds have been determined. There is always one fewer threshold to determine than there are courses of study.

After the Title I program has been applied, the student achievement distribution will shift if the program is effective. In Chapter V, the new expected achievement and standard deviation of achievement are computed. It is assumed that the thresholds defining course of study selection do not change even though the achievement distribution may change. This assumption is generally valid if the achievement changes are small. The thresholds may themselves represent educational policy decisions of a state or city education board, and hence would be unaffected in the short run by changes in the achievement distribution within a given school. The shift in achievement distribution is shown in Figure 2. It should be noted that, because the thresholds differ from student type to student type, equal changes in the achievement distributions of two student types will lead to different changes in course of study selection, reflecting the differing attitudes and values of the student types.

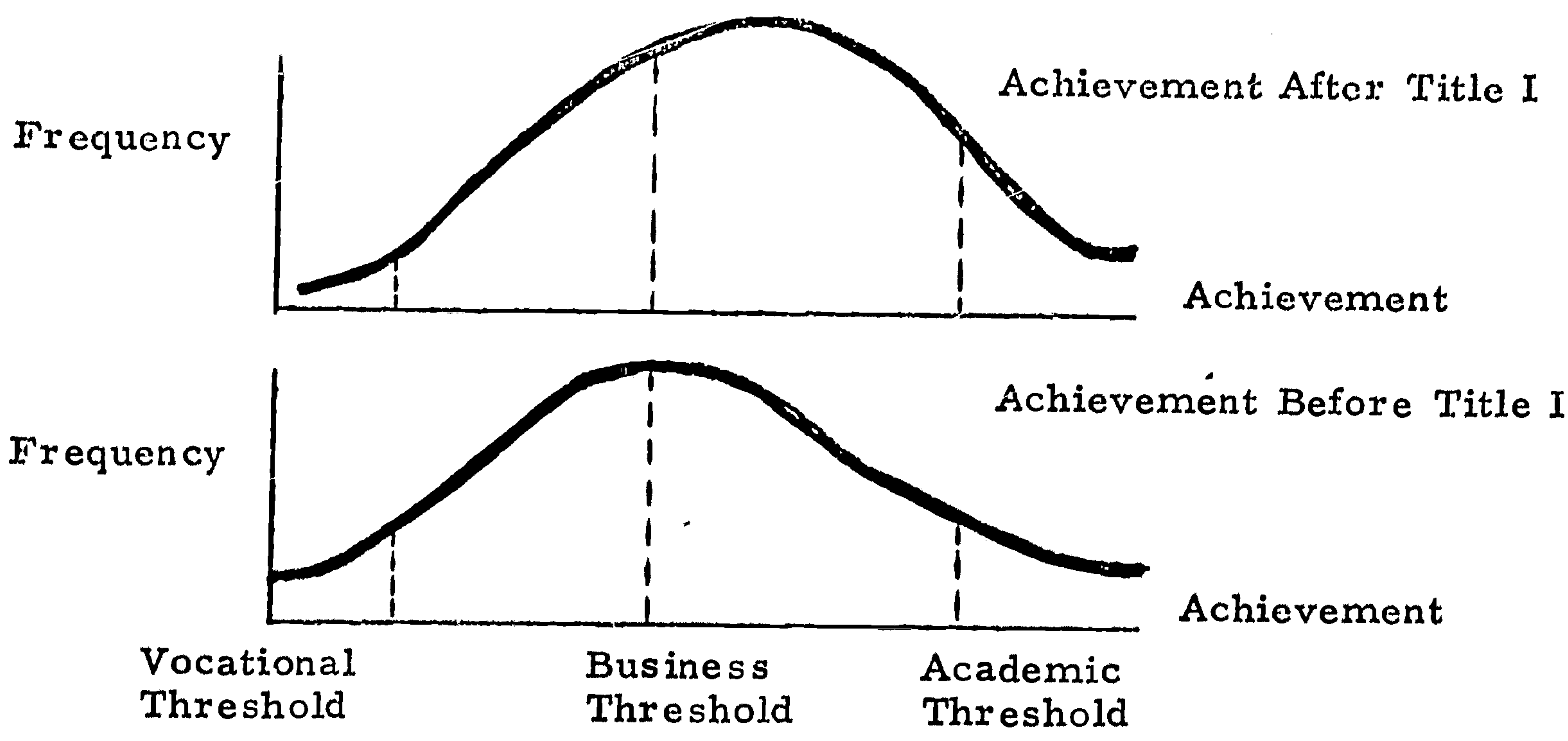


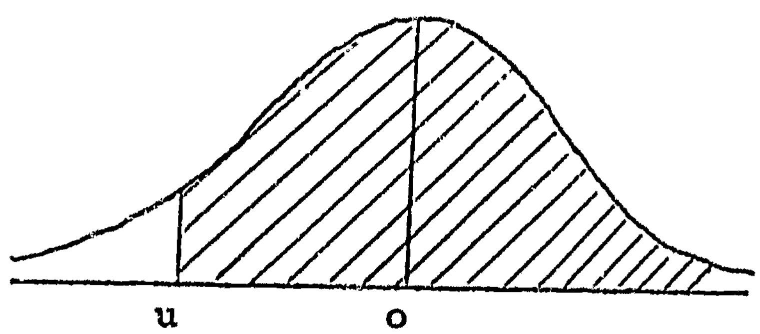
Figure 2

The proportion of students in each course of study after application of a Title I program is equal to the area under the new achievement distribution between the two relevant thresholds which were calculated from the old achievement distribution. If the Title I program does not affect achievement, the two achievement curves are identical, and the proportion of students in each course of study does not change.

After the new proportions have been computed for each course of study, they must be compared with the constraints on enrollment in each course of study set by the school. The reasons for including constraints follow. Changes in achievement distributions for certain student types may suggest a large change in the enrollment in certain courses of study: a trade school with a few college preparatory students might suddenly seem to be a college preparatory school. To attribute a change of this kind to a Title I program is unrealistic; an explicit change in school policy is implied, which is something not considered in the present analysis. The constraints on enrollment in particular courses of study may be caused by school policy or by the scarcity of physical resources, such as typewriters, shop equipment, or teachers. If a school has effectively no such constraints, then such constraints can be ignored in the analysis; if they are used, then the adjustment of proportions to justify the constraints is carried out for each course of study in decreasing order of achievement threshold.

It is a straightforward matter to quantify this projection method. We write A_k and S_k as the expected achievement and standard deviation of achievement before Title I programs for students of a given type in grade k, at which course of study selection is assumed to occur. These achievement measures, after the Title I program has been applied, are written A'_k and S'_k. The numbers of students in each course of study before the Title I program are written $n_1, n_2, \ldots, n_p$, where there are p courses of study. We wish to find the proportions $n'_1, n'_2, \ldots, n'_p$ choosing each course of study after the Title I program. The school sets constraints of $m_1, m_2, \ldots, m_p$ students as the maximum permitted in each course of study. The total number of students of a given type is N, equal to the sum $n_{.} + n_2 + \dots + n_p$, which is also equal to the sum $n'_1 + n'_2 + \dots + n'_p$ and less than or equal to the sum $m_1 + m_2 + \dots + m_p$.

It is assumed that the courses of study are ranked so that the first course of study corresponds to students with highest achievement, the second to the next highest achieving students, and so on. The function $R(u)$ is defined from the tables of the unit normal distribution as the area under the curve to the right of u. This function is illustrated by the shaded area in Figure 3.



Unit Normal Curve

Figure 3

It is assumed that the proportion of students in each course of study before Title I program application has been adjusted so that none of the proportions violates the constraints imposed by the schools; that is, for all courses of study, n is less than or equal to m.

The course of study thresholds are written $B_1, \dots, B_{p-1}$ (there is always one fewer threshold than course of study) and are calculated by

$$R\,[(B - A_k)/S_k] = n2/N$$

$$R\,[(B_2 - A_k)/S_k] - R\,[(B_1 - A_k)/S_k] = n2/N$$

and so on, until the last:

$$1 - R\ [(B_{p-1} - A_k)/S_k] = {}^{n}p/_{N}$$

The last equation serves as a check, because $n_1 + n_2 + \ldots + n_p = N$. Tables of the unit normal distribution and an explanation of their use to compute R(u) are given at the end of this chapter.

The new numbers of students enrolled in each course of study before considering the constraints is given by

$$n'_1 = NR\ [(B_1 - A'_k)/S'_k]$$

$$n'_2 = N\ (R[(B_2 - A'_k)/S'_k] - R\ [(B_1 - A'_k)/S'_k])$$

and so on, until the last

$$n'_p = N\ (1-R\ [(B_{p-1} - A'_k)/S'_k])$$

The constraints are utilized as follows. Define min (a, b) to be the smaller of the two numbers a and b. Define also a surplus variable T_i which represents the number of students who are unable to be assigned to courses of study 1, 2, . . ., i, because of the constraints. Then the constrained proportions of students in each course of study after Title I, written $n_1^*, \ldots, n_p^*$, are given by

$$n_1^* = \min\ (n'_1, m_1)$$

$$n_2^* = \min\ (n'_2 + T_1, m_2)$$

and so on to

$$n_p{}^* = \min(n'_p + T_{p-1}, m_p).$$

where

$$T_{i+1} = T_i + n'_{i+1} - m_{i+1} \qquad i = 0, \ldots, p-1 \text{ and } T_o = 0$$

As a check, $T_p = 0$ if the allocation has been performed properly. The "slack" variable T represents the surplus or deficit of students yet to be assigned.

For example, suppose that students (all of the same type) in grade 10 have an expected achievement of 9.4, in grade level units, and a standard deviation of 1.0. There are three courses of study: college prep, business, and vocational. Out of the 100 students, 20 choose the college prep program, 30 the business program, and 50 the vocational program. Hence, $A_k = 9.4$, $S_k = 1.0$, $n_1 = 20$, $n_2 = 30$, $n_3 = 50$ and $N = 100$. The school sets constraints of 28 in the college prep program, 30 in the business program and 42 in the vocational program, so that $m_1 = 28$, $m_2 = 30$, and $m_3 = 42$.

The achievement thresholds B_1 and B_2 can be computed from normal distribution tables as

$$R\left(\frac{B_1 - 9.4}{1.0}\right) = .2, \text{ or } \frac{B_1 - 9.4}{1.0} = .85, \text{ or } B_1 = 10.25$$

$$R\left(\frac{B_2 - 9.4}{1.0}\right) - .2 = .3, \text{ or } B_2 - 9.4)/1.0 = 0, \text{ or } B_2 = 9.40$$

After the Title I program has been applied, the average achievement is assumed to have increased to 9.7, but the standard deviation remains unchanged. The new proportions in each course of study, temporarily ignoring the constraints are given by

$$n_{1'} = 100 \ R \frac{(10.25 - 9.7)}{1.0} = 29$$

$$n_{2'} = 100 \left\{ R\left(\frac{9.4 - 9.7}{1.0}\right) - R\left(\frac{10.25 - 9.5}{1.0}\right) \right\} = 100 \ (\ .62 - .29 = 33$$

$$n_{3'} = 100 \left\{ 1 \ \frac{(9.4 - 9.7)}{1.0} \right\} = 100 \ (1 - 62) = 38$$

$$T_o = 0$$

$$n_1^* = \min (29, \ 28) = 28 \qquad T_1 = 0 + 29 - 28 = 1$$

$$n_2^* = \min (33 + 1, \ 30) = 30 \qquad T_2 = 1 + 33 - 30 = 4$$

$$n_3^* = \min (38 + 4, \ 42) = 42 \qquad T_3 = 4 + 38 = 42 = 0$$

CHAPTER IX

COMMUNITY EFFECTS SUBMODEL

The discussion thus far has centered on the projection of effects which are directly a part of the actual school environment. The Community Effects Submodel, with which this chapter is concerned, is an attempt to assess the impact of these immediately school-based effects from proposed Title I projects in the larger context of the community in which the target school population is located. Community effects are an important means by which to evaluate the educational system, for one important measure of the effectiveness is the long-term performance of the people who are its product. Two indicators of school-community interaction have been developed. These are: 1) potential lifetime earnings for the various student types as an indication of the economic consequences of education, and 2) an index of equality of educational opportunity for these groups, which indicates the degree to which achievement is associated with socio-economic background.

Potential Lifetime Earnings

The potential earnings subroutine is based on three factors: the grade level at which students drop out of school, the achievement level of those students who graduate from high school, and the courses of study chosen by students who attend schools in which several courses of study are available. These variables are assumed to have a strong effect upon the careers eventually chosen by the students and thus upon their earnings later in life.

The potential earnings portion of the model consists of a distribution routine which determines the expected fractions of the original group of students which will fall into each future earnings category. As shown in Figure 1, it receives inputs describing the achievement of graduating students from the School Flow Submodel, inputs describing the number and type of students choosing the various available courses of study from the Course of Study Selection Submodel, and inputs about the timing of dropouts from the Dropout/Truancy Submodel. A number of studies indicate that there is a strong relationship between such variables as age of leaving school, achievement level of graduates, course of study (and thus to some extent, occupation) chosen by students, and their expected lifetime earnings or expected average salary during their working years. Reports published by the Bureau of the Census and various journal articles indicate that lifetime earnings are related positively to number of years in school, somewhat positively with high school achievement level, and varyingly with occupation (or course of study selected). The model used to calculate potential lifetime earnings incorporates these general relationships, but does not go into the fine detail discussed in some of these articles.

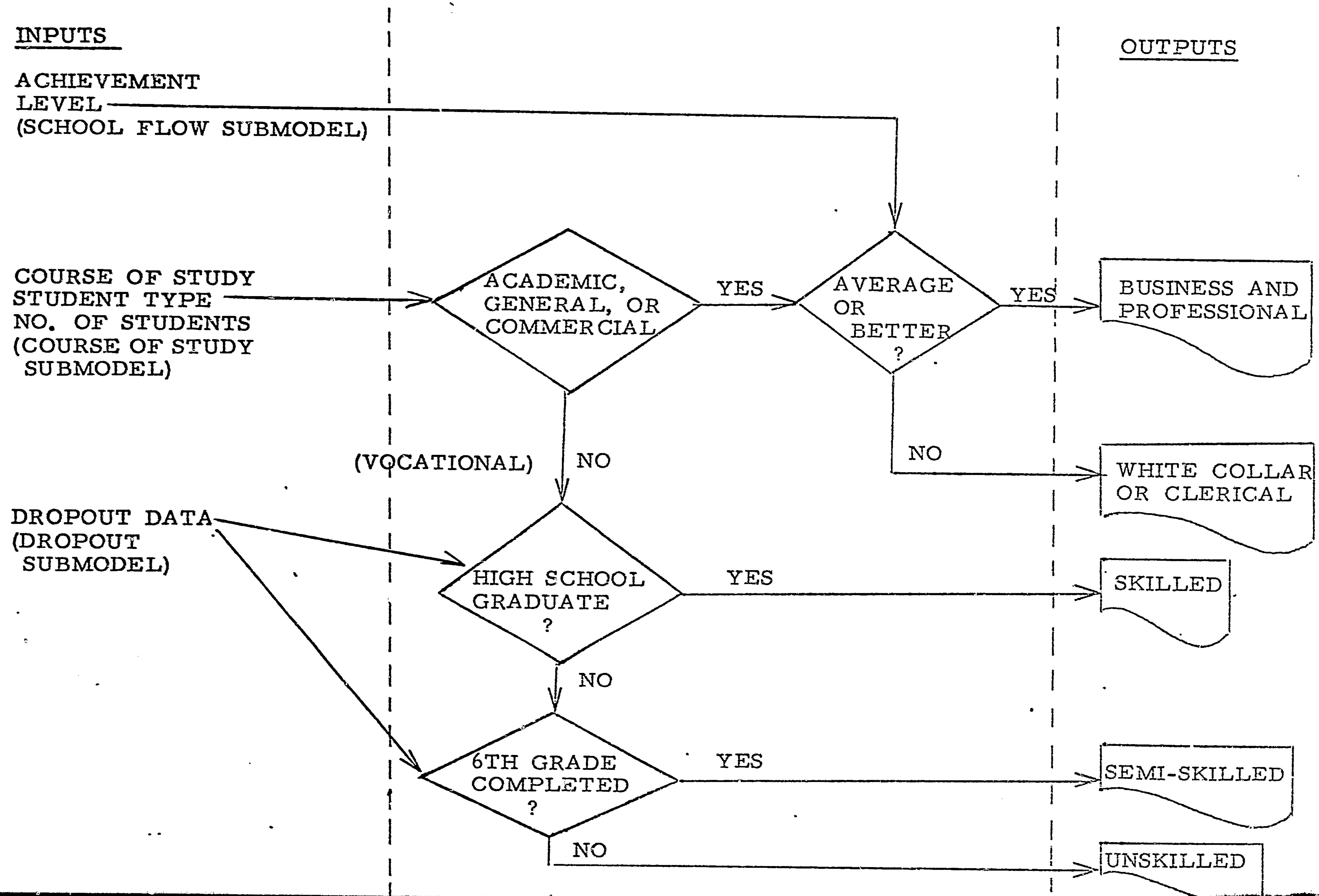
The possibility of discounting the stream of future earnings to determine the present value of future income, of computing the return on present investment of educational programs, or of including growth rates for the economy as a whole and for different occupations as a function of differential demand in computing potential earnings were considered, but were set aside in the interests of a more intensive study of the educational process which is the core of the model.

Index of Equality of Educational Opportunity

The index of equality of educational opportunity is a measure which was devised to indicate the degree to which a school system exercises and develops the potential of all students regardless of socio-economic background. The idea for such an index comes from an article by James S. Coleman, who suggested that the measure of equality of educational opportunity is the degree to which each student is equipped at the end of school to compete on an equal basis with others, whatever his social origins. Another way of putting this is to say that the schools are successful only insofar as they reduce the dependence of a student's opportunities upon his social origins - equality of educational opportunity

POTENTIAL LIFETIME EARNINGS SUBROUTINE

Figure 1



implies schools whose influences will overcome the differences in starting point of children from different social groups.*

In order to compute an index of equality of educational opportunity, it is important to look at the change in achievement differences among student types during their school career. To the extent that a proposed Title I program lessens these achievement differences by the time of graduation, to that extent it contributes to increased equality of educational opportunity.

The measure of equality of educational opportunity which we have devised to implement Coleman's concept is computed as follows. Achievement distributions of first grade students will be available to the model as part of the input data. We assume that inter-group achievement level differences at this point are due primarily to differences in the respective groups' home environments and, therefore, we take these differences to be our baseline, i.e., to represent the initial inequalities which the school system seeks to eliminate. Using the procedures described in Chapters V and VI, the model computes the effect of a proposed Title I program on achievement distributions at graduation. If by the time of graduation these differences have increased, the school has contributed to the pre-existing disparities among the student types, and the school has provided unequal educational opportunities to its students. In output terms, this situation would be represented by a low value for the index of equality educational opportunity.

In more quantitative terms, the model performs the following calculations. Suppose that we write $\overline{A}_{ij}$ for the expected achievement at grade j for student type i. Then $\overline{A}_{i1} - \overline{A}_{k1}$ represents the difference in achievement between two student types in the first grade. Similarly, $\overline{A}_{ij} - \overline{A}_{kj}$ represents the difference in achievement between two student types in the j^{th} grade. A measure of the change in educational opportunity for student types i and k from the first to the j^{th} grade is

*James S. Coleman, "Equal Schools or Equal Students?", The Public Interest, 1966, 4, 70-75.

$$e_{ik}(j) = 1 - \left| \frac{(\overline{A}_{i1} - \overline{A}_{k1}) - (\overline{A}_{ij} - \overline{A}_{kj})}{12} \right|$$

The closer this index is to one, the more nearly equal is educational opportunity.

The calculation of $\overline{A}_{ij}$, etc., is described in Chapter VI. If the expected achievements after application of a Title I program are denoted by $\overline{A}^*_{ij}$, etc., then

$$\Delta e_{ik}(j) = e^*_{ik}(j) - e_{ik}(j)$$

$$= \frac{\left| \overline{A}_{i1} - \overline{A}_{k1} - \overline{A}_{ij} + \overline{A}_{kj} \right| - \left| \overline{A}^*_{i1} - \overline{A}^*_{k1} - \overline{A}^*_{ij} + \overline{A}^*_{kj} \right|}{12}$$

represents the change in equality of educational opportunity due to a Title I program. If the program increases equality of education, the measure $\Delta e_{ik}(j)$ will be positive.

The measures presented are given in relative terms. It may also be of interest to test hypothesis concerning the absolute measures of achievement differences, based on the assumption that the expected achievement for different student types at first grade is fixed.

If $(\overline{A}^*_{ij} - \overline{A}^*_{kj})$ is taken as the measure of inequity of achievement between student types i and k at grade j, then, by the assumptions of Chapter VI, the measure is normally distributed with mean $\overline{A}_{i1} - \overline{A}_{k1}$ under the null hypothesis of no change in equality, and variance $\frac{1}{n}\left\{\sigma^2_{ij} + \sigma^2_{kj} - 2\rho_{ikj}\sigma_{ij}\sigma_{kj}\right\}$, where ρ_{ikj} is the correlation between an achievement score for student type i at grade j and a score for student type k at grade j; n is the number of students on whom the computations of $\overline{A}_{ij}$ is based.

The projected achievement values after Title I can be tested to see if they differ significantly from the previous values by using tables of the normal distribution if $n \geq 30$. Hence,

$$\frac{\sqrt{n}\left\{(\overline{A}^*_{ij} - \overline{A}^*_{kj}) - (\overline{A}_{i1} - \overline{A}_{k1})\right\}}{\left\{\sigma^2_{ij} + \sigma^2_{kj} - 2\rho_{ikj}\sigma_{ij}\sigma_{kj}\right\}^{1/2}} = z$$

is the test statistic, and if $z \leq -1.64$, there has been a significant (at the 95% level) improvement in equality of educational opportunity at grade j, if $z \geq 1.64$, a significant lessening in equality of educational opportunity has occurred. At $-1.64 \leq z \leq 1.64$, no significant change has occurred.

It should be noted that the use of hypothesis testing should be for information and guidance, but not as an absolute decision procedure, especially because the results of this section are approximate. The value for ρ_{ikj} should be determined from historical data or by judgment; estimated values of $\hat{\rho}_{ikj}$ which are smaller than the true value gives conservative tests in that quantities which are in fact significant do not appear so. If many tests or comparisons are to be made, then the 5% level should be replaced by a significance level (e.g., 5%) divided by the number of tests or comparisons to be made, so that the overall comparisons are valid. The threshold 1.64 should be changed appropriately.

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CHAPTER X

THE EFFECTIVENESS OUTPUTS SUBMODEL

Throughout all phases of the modeling effort, it has been our intent to design a system that will be of service to those responsible for the final evaluation of proposed Title I programs. It is not claimed that the OECE model will solve all their problems, but rather that it can provide education decision-makers with additional information on which to base their decisions. Every attempt has been made to insure that such information will be both meaningful and useful.

The great mathematician Norbert Weiner once remarked that the trouble with computers is exactly the same as the trouble with magic--they give us only what we ask for, not what we should have asked for. With this in mind, much of the work has been devoted to a careful and highly critical selection, among possible model outputs, of those which, in the estimation of both the Title I group at OE and the Abt Associates Inc. staff, seemed most useful. But simply selecting the most useful outputs is not enough. Equally important is the manner in whcih these outputs are presented. Data, when presented poorly, is of limited usefulness and often misleading. A computer with a high-speed printer is capable of creating more printed data in an hour than a man can read in a week--this is both its weakness and its strength. A computer can serve a few men poorly--by overloading them with half-interesting mountains of data--or it can serve many men well--by providing clear and concise summaries of the results of its complex computations. Which it will do depends on the way its output is presented. Ideally, the report generated by the computer must be presented and organized for maximum convenience to the planner.

To achieve this convenience, the project group has selected, in consultation with the Title I group at the Office of Education, a two-part presentation of the model outputs: (1) a summary page, designed to give the planner a quick overview of the projected effects of a proposed Title I program, and (2) several pages of more detailed information, designed to give the planner a more specific breakdown of the information presented in the summary page. Since Title I project evaluators are interested in seeing the changes effected by proposed programs, both parts of the output presentation provide not only a projection of the results after the program under consideration has run its course, but also a point-for-point set of comparison data which describe the situation as it exists prior to the initiation of the Title I program.

Often, the decision-maker will wish to compare two or more alternative Title I projects for the same school district. This is readily accomplished by comparing the model's projected results for each of the proposed alternatives. Notice that here the model provides a particularly useful service. Alternative proposals may differ over a wide range--they may be directed at different grades, different subjects, and different target groups. The more they differ, the more difficult it is for a planner to compare their relative merits. The strength of the OECE model is that it has been designed to accept and evaluate highly dissimilar proposals in commensurate terms, e.g., achievement levels, etc., but in order for this strength to be fully employed, it is necessary that the decision-maker understand intuitively the internal functionings of the model. This is not to claim that decision-making on the basis of model projections of program results will suddenly become a simple process, but that the model can provide an important part of the information upon which a final decision is made. Indeed, the most important part of the model is the person who uses it. The model will present reasonable predictions of the effects of proposed programs, but it is the user who must weigh these possible effects against each other on the basis of his expertise and come to a definite conclusion. This, we feel, is the proper relationship between man and model.

As has been stated earlier, current knowledge of the relevant educational, learning, and sociological processes is not sufficient to construct a model which can predict precisely the changes in a school system and community that might result from the introduction of Title I programs into the schools. However, using current knowledge, one is realizable which will make reasonable predictions which may be compared across a series of proposed programs. This procedure avoids the potential error of regarding the results as absolute predictions, minimizes the model biases, and provides relative measures of different programs' advantages and disadvantages.

The Effectiveness Outputs Submodel is the communications link between the actual evaluative submodels described in Chapters V through IX and the user. It receives the calculated outputs from the evaluative submodels and prints them in the form of a report for the user. As mentioned above, the report has two parts: (1) an overall summary (Figure 2) and (2) a more detailed breakdown of the summarized data. Part two is divided into a detailed section on achievements (Figure 2) and a detailed section on dropouts and attendance (Figure 3). Since primary emphasis is placed on the changes which result from the introduction of a Title I program, the output report for each project run includes a parallel set of baseline data which the model calculates from the input data characterizing the school district but excluding any proposed program data. Baseline data are indicated in the report by the heading:

BEFORE PROJECT
YEAR: 19xx

The Title I projected results are indicated by the heading:

AFTER PROJECT
YEAR: 19xx

Where appropriate, data in the summary and in the achievement section are broken down by the sociological characteristics of the students. As noted in the previous chapters, the student body is divided, for the purposes of the model, into four socio-economic groups. Data for the individual groups appears under the heading:

STUDENT
TYPE

where the types are:

Type 1 -- non-whites with annual family income less than or equal to a threshold T, currently set at $2000

Type 2 -- non-whites with annual family income greater than T

Type 3 -- whites with annual family income less than or equal to T

Type 4 -- whites with annual family income greater than T

Summary Page

The overall summary (Figure 1) shows the effects of a Title I program on the school and community. Average achievements, values for the index of impedance to instruction, number of dropouts, and number of graduates are listed under the heading:

SCHOOL IMPACTS

These are defined as follows:

1. Average Achievement is the average of student achievement grade levels in all subjects. It is given at the target grade and at the twelfth grade. If the target group spans more than one grade, the average is given for the highest grade. (See Chapters V and VI.)

2. Index of Impedance to Instruction is a measure of the incidence within a student type of certain characteristics thought to be detrimental to the students' receptivity to instruction. Index values range from one to ten. High values indicate that the characteristics of the student's environment would tend to place him at a disadvantage in the school learning situation, low values indicate fewer environmental disadvantages. (See Chapter VI.)

3. Number of Dropouts is the total number of students from the target population expected to leave school before graduation. (See Chapter VII.)

4. Number of Graduates is the total number of students from the target population expected to graduate. (See Chapter VII.)

Data indicating projected degree of equality of educational opportunity and expected average lifetime earnings appear under the heading:

COMMUNITY IMPACTS

Index of Equality of Educational Opportunity indicates the degree to which students' educational achievement is dependent upon their socio-economic background. (See Chapter IX.) The index in the summary is scaled so that if the condition of perfect equality is met, i.e., academic levels are not limited by socio-economic background, the index will be one; if complete inequality occurs, i.e., achievement levels are completely determined by socio-economic factors, the index will be zero.

Expected Average Lifetime Earnings are projected for each of the four student types and included on the summary page.

Achievements

In addition to the information in the overall summary, more detailed data is provided about academic achievement (Figure 2). Achievements are given in grade levels; e.g., a student reading at the beginning fourth grade level has an achievement level of 4.0 in reading regardless of the grade he is actually in. These levels are shown for the average student of each student type, for twelve grades, in up to six academic subjects.

Dropouts and Attendance

Information about the number of dropouts and the attendance rate is provided in a graphical format (Figure 3). These graphs give a twelve grade breakdown for the entire school population; i.e., the individual figures about dropouts and attendance for each grade are not disaggregated by student type. The attendance percentage is based upon total student days, which equals the number of students multiplied by the number of school days.

SUMMARY OUTPUT

U.S.O.E. COST-EFFECTIVENESS MODEL

COMMUNITY:	FERNDALE MASS	PROJECT TYPE:	REMEDIAL READING
TARGET POPULATION:	G2-3 SCHOOL B	ANNUAL COST:	85000

SCHOOL IMPACTS

	STUDENT TYPE	AVERAGE ACHIEVEMENT TGT-G	G-12	INDEX OF IMPEDANCE TO INSTR	NUMBER OF DROPOUTS	NUMBER OF GRADUATES
BEFORE PROJECT, YEAR: 1965	1	1.2	8.6	8.6	20	28
	2	2.0	10.3	8.4	16	31
	3	1.4	7.9	8.0	21	27
	4	3.2	12.0	5.6	9	46
AFTER PROJECT, YEAR: 1967	1	1.8	10.2	7.3	16	32
	2	2.6	11.0	6.9	12	35
	3	2.4	11.2	5.8	17	31
	4	3.2	12.0	5.6	8	47

COMMUNITY IMPACTS

EQUALITY OF EDUCATIONAL OPPORTUNITY

	BEFORE PROJECT, YEAR: 1965	AFTER PROJECT, YEAR: 1967
COMBINED	.40	.50
BY INCOME GROUPS	.35	.40
BY ETHNIC GROUPS	.18	.27

EXPECTED AVERAGE LIFETIME EARNINGS

STUDENT TYPE	BEFORE PROJECT, YEAR: 1965	AFTER PROJECT, YEAR: 1967
1	$ 200000	$ 275000
2	$ 300000	$ 400000
3	$ 325000	$ 400000
4	$ 450000	$ 500000

STUDENT TYPES

1 NON-WHITES UNDER 2000 INCOME 3 WHITES UNDER 2000 INCOME
2 NON-WHITES OVER 2000 INCOME 4 WHITES OVER 2000 INCOME

FIGURE 1

ACHIEVEMENT OUTPUTS
BY GRADE, SUBJECTS, AND POPULATION TYPES

COMMUNITY:	FERNDALE MASS	PROJECT TYPE:	REMEDIAL READING
TARGET POPULATION:	G2-3 SCHOOL B	ANNUAL COST:	85000

GRADE LEVELS IN LANGUAGE

	STUDENT TYPE	GRADE 1	2	3	4	5	6	7	8	9	10	11	12
BEFORE	1	.6	1.1	1.6	2.3	3.0	3.8	4.5	5.2	7.0	7.6	8.2	8.9
PROJCT	2	.8	1.2	1.9	2.9	3.4	4.5	5.1	6.0	7.7	8.4	9.3	10.0
YEAR:	3	.8	1.3	2.0	3.1	3.7	4.9	5.8	6.6	8.6	9.2	9.9	10.9
1965	4	1.2	2.1	2.9	4.0	5.0	6.2	7.1	8.0	9.3	10.2	11.0	12.0
AFTER	1	.6	1.4	2.9	3.0	3.9	5.8	6.7	7.6	8.5	9.4	10.3	11.0
PROJCT	2	.8	1.5	3.0	4.0	5.0	6.0	6.9	7.9	8.9	9.9	10.9	11.6
YEAR:	3	.8	1.7	3.1	4.0	5.2	6.2	7.1	8.0	9.0	10.0	11.0	12.0
1966	4	1.2	2.1	2.9	4.0	5.0	6.2	7.1	8.0	9.3	10.2	11.0	12.0

GRADE LEVELS IN MATHEMATICS

	STUDENT TYPE	GRADE 1	2	3	4	5	6	7	8	9	10	11	12
BEFORE	1	.5	1.1	1.8	2.3	3.0	3.6	4.4	5.0	5.8	6.3	7.0	7.7
PROJCT	2	.8	1.3	2.2	2.9	4.0	4.6	5.5	6.1	7.0	8.0	8.1	8.8
YEAR:	3	.9	1.5	2.7	3.1	4.1	5.0	6.7	6.6	7.2	8.0	8.1	8.8
1965	4	1.0	2.0	2.9	3.9	5.0	6.2	7.1	8.0	9.1	10.0	11.1	12.0
AFTER	1	.5	1.3	2.2	3.0	4.0	4.6	5.4	6.0	6.7	7.2	8.0	8.8
PROJCT	2	.8	1.8	2.9	3.9	5.0	5.6	6.5	7.1	8.1	8.4	8.5	9.0
YEAR:	3	.9	2.0	3.0	4.1	5.0	6.0	7.0	8.0	8.8	9.0	9.1	9.4
1968	4	1.0	2.1	3.0	4.2	5.1	6.0	7.0	8.0	9.0	10.0	11.0	12.0

GRADE LEVELS IN SCIENCE

	STUDENT TYPE	GRADE 1	2	3	4	5	6	7	8	9	10	11	12
BEFORE	1	.6	1.4	2.9	3.0	3.9	5.8	6.7	7.6	8.5	9.4	10.3	11.0
PROJCT	2	.8	1.5	3.0	4.0	5.0	6.0	6.9	7.9	8.9	9.9	10.9	11.6
YEAR:	3	.8	1.7	3.1	4.0	5.2	6.2	7.1	8.0	9.0	10.0	11.0	12.0
1965	4	1.2	2.1	2.9	4.0	5.0	6.2	7.1	8.0	9.3	10.2	11.0	12.0
AFTER	1	.6	1.1	1.6	2.3	3.0	3.8	4.5	5.2	7.0	7.6	8.2	8.9
PROJCT	2	.8	1.2	1.9	2.9	3.4	4.5	5.1	6.0	7.7	8.4	9.3	10.0
YEAR:	3	.8	1.3	2.0	3.1	3.7	4.9	5.8	6.6	8.6	9.2	9.9	10.9
1968	4	1.2	2.1	2.9	4.0	5.0	6.2	7.1	8.0	9.3	10.2	11.0	12.0

STUDENT TYPES: 1-NONWHITES, LESS THAN 2000 3-WHITES, LESS THAN 2000
2-NONWHITES, MORE THAN 2000 4-WHITES, MORE THAN 2000

FIGURE 2

ATTENDANCE AND DROPOUT OUTPUTS

COMMUNITY: FERNDALE MASS

PROJECT TYPE: REMEDIAL READING

TARGET POPULATION: G2-3 SCHOOL B

ANNUAL COST: 85000

PER CENT ATTENDANCE BEFORE PROJECT YEAR: 1965

	1	2	3	4	5	6	7	8	9	10	11	12
95-100												
90- 94		90	90		93	92	94					
85- 89	85							89				
80- 84				83					81		80	
75- 79										78		76
70- 74												
65- 69												
60- 64												
55- 59												
50- 54												
0- 49												
GRADE	1	2	3	4	5	6	7	8	9	10	11	12

PER CENT ATTENDANCE AFTER PROJECT YEAR: 1967

	1	2	3	4	5	6	7	8	9	10	11	12
95-100							96					
90- 94		90	90		93	91		90				
85- 89	85			85					87	85		
80- 84											80	84
75- 79												
70- 74												
65- 69												
60- 64												
55- 59												
50- 54												
0- 49												
GRADE	1	2	3	4	5	6	7	8	9	10	11	12

NUMBER OF DROPOUTS PER GRADE BEFORE PROJECT YEAR: 1965

	1	2	3	4	5	6	7	8	9	10	11	12
45- 50												
40- 44												
35- 39												
30- 34												
25- 29												
20- 24											20	
15- 19												16
10- 14										14		
5- 9								6	7			
0- 4	0	0	0	0	0	2	0					
GRADE	1	2	3	4	5	6	7	8	9	10	11	12

NUMBER OF DROPOUTS PER GRADE AFTER PROJECT YEAR: 1967

	1	2	3	4	5	6	7	8	9	10	11	12
45- 50												
40- 44												
35- 39												
30- 34												
25- 29												
20- 24												
15- 19												
10- 14												
5- 9									5	8	9	7
0- 4	0	0	0	0	0	0	1	2				
GRADE	1	2	3	4	5	6	7	8	9	10	11	12

FIGURE 3

CHAPTER XI

RECOMMENDATIONS FOR FURTHER RESEARCH

The design of the present cost-effectiveness model raised many new questions which require further investigation if the effectiveness of public education is to be improved. If current educational research were to address itself to the following areas of investigation, comprehensive evaluation techniques for educational change could be much improved. For convenience, the recommendations suggested by this study are divided into substantive and methodological research categories.

Substantive Research should be conducted to determine:

1. Operationally defined and measurable indicators of teaching effectiveness that require only commonly obtainable data;

2. The relative contributions of home, peer influence, and school instruction to student achievement;

3. The relative contributions of service and instructional improvement projects to student achievement change for various absolute levels of service and instruction;

4. The existence of a minimum standard in school service provisions and/or level of instruction which need to be met before significant improvement can be expected in student attitudes and achievement;

5. The relative quantitative contribution of the actual variables in the school environment which contribute most heavily to student attitude and achievement change (through protocol models of classroom response patterns, small group research, and role model analysis);

6. The coefficient and parameter settings for the environmental influences on student attitude and achievement change with enough accuracy to allow useful prediction;

7. A generalized classification system for community types to minimize data needs (a number of communities of a given type would be able to use one data base);

8. The differential effects of various teaching strategies on various student types;

9. The impact of Title I projects on the attitudes and behaviors of the parents of affected students, and parent feedback effects on student attitudes and achievements;

10. The impact of Title I projects on the social, cultural, economic, and political structures of the community and the community's feedback to the education system;

11. The later effects of early academic failures and the later effects of early academic successes;

12. Student interest and achievement sensitivity to the sequencing of subject matter;

13. The impact the overall organizational character of a school has on the performances of various student types;

14. The impact of multiple and inter-school programs on the performance of the students and on the attitudes of the administrators, and how changes in the latter in turn affect the former;

15. The impact of the newly racially-integrated schools (Project METCO in Boston, Massachusetts, for example) on white and non-white student performances;

16. Guidelines, based on the implications of the model, for the changing role and character of the urban education system;

17. An expanded community submodel to include demographic and occupational forecasts of job supply and demand, especially in education;

18. The relationship of later economic and social status to particular school variables to help derive measures of value for school changes.

Methodological Research should be conducted to:

1. Program the present model for computer operation;

2. Test the model with real data drawn from several project histories;

3. Compile a handbook for Title I proposers which would give guidelines by community type for the kinds of projects likely to yield the most benefit;

4. Determine the availability and comparability of school and community data across school districts;

5. Develop improved data collection procedures to support the model effort;

6. Explore alternative techniques for extrapolating the long-range effects of changes in achievement (the present School Flow Submodel is a single-stage Markov process);

7. Examine the possibilities of using the cost-effectiveness model in all phases of Title I administration from project proposal to approval and implementation.

APPENDIX A

A DIFFERENCE EQUATION MODEL OF THE IMPACT OF SUPPLEMENTAL EDUCATION PROGRAMS: A SUMMARY

Introduction

We consider that the impact of a supplemental education program on the students of a school occurs during the year at which the program is applied, over the remainder of the school career of the students, and after schooling, as projected community impact. We further consider that an impact is two-fold: it modifies, over these three time periods, the average achievement level of particular student types or classes, and it alters the expected number of students in non-academic courses of study and the number who are dropouts and truants.

Based on these general assumptions and some more specific ones, it is possible to construct a system of difference equations which can be used to simulate the impact of supplemental education programs on a particular school, relative to alternative programs. These difference equations are qualifications of existing educational and sociological theory, and require only a limited amount of historical data.

2. Mathematical Representation of Students in a Given Grade.

Students in a given grade are stratified by student type, e.g., white with family annual income less than $2,000, non-white with family income greater than $2,000 per year, and by course of study, e.g., vocational, commercial, academic. In schools where no course of study separation is permitted, this disaggregation is not considered. Students of a particular type in a particular course of study in a given grade are further classifiable by behavior, e.g., dropout, truant, death, etc. We denote the number of students of type i in course of study j in grade k by n_k^{ij} and add a second subscript to indicate behavioral classification: $n^{ij}_{k,\text{truant}}$ is the number of students of type i in course of study j in grade k who are truants.

In a given grade, there are a fixed number, r, of subjects offered. For each subject a pass-fail or satisfactory-unsatisfactory threshold can be defined (the generalization to three or more classifications is restricted only computationally), and each student is given a 1 or 0 as he surpasses or does not surpass the threshold for that subject. If this assignment is made for each student of type i in course of study j, then a vector of r binary digits can be defined for each student. If there are r subjects, then it is clear that there are 2^r possible vectors. Each vector corresponds to a state, e.g., in the two subject case, pass English, fail math, and fail English, fail math are two of the four possible states. We denote the proportion of students of type i in course of study j in grade k in a state s (corresponding to the s^{th} vector of i's and o's, $s = 1, \ldots, 2^r$) by $P^{ij}_k(s)$. The vector of proportions with 2^r elements defined by $P^{ij}_k(s)$ over s is called the probability of state vector at time k for the i^{th} student type in the j^{th} course of study, and is written P^{ij}_k. It is clear that

$$\sum_{S=1}^{2^r} P^{ij}_k(s) = 1.$$

A student of type i in the j^{th} course of study in grade k has an academic record represented by his state vector s. In grade k + 1, he has a new (or possibly the same) state vector s'. The proportion of students of type i in course of study j who, given that they had a state vector s in grade k, went on to have a state vector s' in grade k + 1 is written $P^{ij}_k(s'/s)$. The matrix of all 2^{2r} proportions of students of type i in the j^{th} course of study who, given their state in grade k, went on to a state in grade k + 1, is written $\underline{P}^{ij}_k$. The rows in the matrix $\underline{P}^{ij}_k$ correspond to the states at grade k, and the columns to the states at grade k + 1.

Because achievement is closely related to the state vectors $P_k^{ij}(s)$, it is possible to compute from them an expected achievement index. These quantities are written A_k^{ij} and G_k^{ij}, respectively.

We assume that students in grade k can be characterized by their student types, courses of study, behavior, their probability of state vectors, and the transition matrix which is used to determine their stat vectors in grade k + 1. The difference equations describing the impact of supplemental programs on students determine how student distribution over these characteristics changes when the program is applied over the school life of the student and later in terms of their earning capacity and equality of educational opportunity. All of the difference equations depend on these characteristics.

3. Derivation of Baseline Conditions

The probability of state vectors P_k^{ij} and transition matrices $\underline{P}_k^{ij}$ for k = 0, ..., are assumed to be known or estimable from historical data. The estimation procedure is adaptive, based on Bayesian statistical methods, in that it combines data, as it becomes available, with initial subjective estimates for the proportions involved. The time k = 0 is defined as the grade at which the supplemental program is applied.

The achievement index statistics at each grade are determined from the probability of state vectors as follows. For each state vector s with r binary elements, there is a number $\gamma(s)$ defined as the number of unit elements of the vector. For the two subject example, pass English and fail math, $\gamma(s)=1$; failing both yields $\gamma(s)=0$. The expected achievement at each grade for each student type in each course of study is determined recursively as

$$A_{k+1}^{ij} = A_k^{ij} + \sum_{s=1}^{2^r} P_{k+1}^{ij}(s)\,\gamma(s)/r, \text{ where } A_{-1}^{ij} = 0 \tag{1}$$

and the standard deviation of achievement in grade k + 1, conditional on achievement in grade k for the i^{th} student type in the j^{th} course of study is

$$\sigma^{ij}_{k+1} = \left\{ \sum_{s=1}^{2^r} P^{ij}_{k+1}(s)\left(\gamma(s)\right)^2 - \left(\sum_{s=1}^{2^r} P^{ij}_{k+1}(s)\gamma(s) \right)^2 \right\}^{1/2} \qquad (2)$$

The statistics (1) and (2) are predicated on the assumption that the number of subjects passed is a measure of achievement; the first two moments of that random variable can be calculated from the probability of state vector as shown.

The number of students in the k^{th} grade of type i in the j^{th} course of study with a particular behavior pattern is assumed to be available from school records. The set of these members satisfies certain balance and continuity restrictions as follows:

$$m^{ij}_k - n^{ij}_{k,\text{ dropout}} + n^{ij}_{k,\text{ net transfer}} = m^{ij}_{k+1} \qquad (3)$$

$$\sum_{ij} m^{ij}_k = M_k \qquad (4)$$

$$n^{ij}_{k,\text{ active}} + n^{ij}_{k,\text{ active}} = m^{ij}_k \qquad (5)$$

The first equation is a continuity restriction. The subscript "net transfer" refers to a net of transfers into the school less deaths and transfers out of the school. The variable m_k^{ij} comprises, as is shown in (5), the number of students of type i in course of study j in grade k who are enrolled in the school at the beginning of grade k; the subscript "active" has no subjective connotation. Dropouts and transfers are assumed to occur at the end of the k^{th} grade. Equation (4) defines the total number of students in the k^{th} grade.

4. Impact at Time of Application of the Program.

4.1 Change in Probability of State Vector P_o^{ij}

It is assumed that every supplemental program can be defined in terms of environmental (school and community) and psycho-social variables and its relevance to them. A particular set of relevant variables measuring the quantity, quality, and duration of a program, its relevance to the school and community environments for which it is intended, and certain other characteristics has been defined. For each supplemental program, measures are calculated which determine whether or not the program has improved the quality of the education available to students affected, of the i^{th} type in course of study j, in the target grade o, and whether or not it has reduced their impedance to learning. From these measures, the fractional improvement in instruction in subject L for i^{th} student type in course of study j in the target grade can be determined as f_L^{ij}, and the reduction of impedance, a positive number, can be determined for each student type and course of study as f_s^{ij}.

A particular state s can be expected to have a higher proportion of students in it than before the program if the program is beneficial and if the state corresponds to passing a large number of subjects. If the L^{th} component of s, corresponding to subject L, is unity, because it is assumed that the proportion of people passing the L^{th} subject does not decrease after a beneficial program, the contribution of that subject to the new proportion of students in state s is positive. If that component is negative, its contribution to the probability of state is negative. Similarly, if half or more subjects are passed in a state, the reduction in impedance is assumed to imply an increase in the proportion of students in that state.

Specifically, the new probability of state s in the target grade for the i^{th} students type in the j^{th} course of study is

$$r_o^{ij}(s) = P_o^{ij}(s) + \sum_{L=1}^{r} (-1)^{1-v_L(s)} a_L^{ij} f_L^{ij} + (-1)^{r/2-\gamma(s)} a_L^{ij} f_L^{ij} \qquad (6)$$

subject to the restriction that

$$-P_o^{ij}(s) \leq \sum_{L=1}^{r} (-1)^{1-v_L(s)} a_L^{ij} f_L^{ij} + (-1)^{r/2-\gamma(s)} a_s^{ij} f_s^{ij} \leq 1-P_o^{ij}(s) \qquad (7)$$

for r, the number of subjects, an even number.

The variable v (s) is defined as 1 if the L^{th} component of s is unity, and zero if it is zero. The constants a_L^{ij} and a_s^{ij} are set _a priori_ based on educational theory. Equation (7) is a restriction constraining the new probabilities of state to lie between zero and one.

4.2 <u>Change in Achievement Statistics at the Target Grade</u>

Given the probability of state vector with elements defined by (6) and (7), one can determine the change in achievement statistics for the target population by using expressions like (1) and (2).

$$\Delta A_o^{ij} = \sum_{s=1}^{2^r} (r_o^{ij}(s) - P_o^{ij}(s))\gamma(s), \qquad (8)$$

and

$$\Delta \sigma_o^{ij} = \left\{ \sum_{s=1}^{2r} r_o^{ij}(s)\,(\gamma(s))^2 \left(\sum_{s=1}^{2r} r_o^{ij}(s)\gamma(s) \right)^2 \right\}^{1/2} - \left\{ \sum_{s=1}^{2r} P_o^{ij}(s)(\gamma)(s))^2 - \left(\sum_{s=1}^{2r} P_o^{ij}(s)\gamma(s) \right)^2 \right\}^{1/2} ($$

4.3 Change in the Number of Dropouts in the Target Grade

It has been shown in the sociological literature that dropouts are a function of environmental factors, student psychological factors, and achievement, for a particular student type and course of study. We write

$$n_{o\text{, dropout}}^{ij} = f\,(c, z\,,\; A) \tag{10}$$

as a mathematical expression of this qualitative result. It is assumed that the supplemental programs affect only the psycho-social factors, by reducing impedence, and achievement, as shown in § 4.2. The new number of dropouts in the target grade is given by

$$n_{o\text{, dropout}}^{ij} + \Delta n_{o\text{, dropout}}^{ij} = f\,(c, z^{ij} + f_s^{ij},\; A_o^{ij} + \Delta A_o^{ij}) \tag{11}$$

If we expand (11) in a one-term Taylor's series and subtract (10), the result is

$$\Delta n_{o\text{, dropout}}^{ij} = \frac{\partial f}{\partial z}\; f_{ss}^{ij} + \frac{\partial f}{\partial A}\; \Delta A_o^{ij} \tag{12}$$

by assuming that the function f is almost linear in f and A in the region of interest, we have, approximately,

$$\Delta n_{o\text{, dropout}}^{ij} = \alpha_o^{ij}\, f_s^{ij} + \beta_o^{ij}\, \Delta A_o^{ij}\,, \tag{13}$$

subject to the restriction that the lefthand side of (11) is non-negative. The variables on the righthand side of (13) have been calculated in 4.1 and 4.2; the parameters are set initially on the basis of educational theory, and modified adaptively using Bayesian regression methods as observations on (13) become available.

4.4 Change in the Number of Truants in the Target Grade

Because data and sociological theory for truants are less well specified even than that for dropouts, it is difficult to construct an elaborate model. One can make an argument similar to that for dropouts, and conclude that an approximate representation of the change in the number of truants of type i in the j^{th} course of study in the target grade is

$$\Delta n_{o,\ truant}^{ij} = \delta_o^{ij} f_s^{ij} + \phi_o^{ij} \Delta A_o^{ij}, \tag{14}$$

subject to the non-negativity of $n_{o,\ truant}^{ij} + \Delta n_{o,\ truant}^{ij}$ where the parameters are to be estimated adpatively.

5. Yearly Impact Until the Class Graduates

5.1 Change in Probability of State Vectors and Achievement Indices at Grade k+1

The change in probability of state vectors is determined based on the assumptions of a Markov process, in which the initial state vector is modified repeatedly by a one-step transition matrix. The change in probability of state vector is determined recursively by

$$r_{k+1}^{ij} - P_{k+1}^{ij} = \underline{P}_{k+1}^{ij} (r_k^{ij} - P_k^{ij}), \quad k=0,\ldots \tag{15}$$

where r_o^{ij} is determined in 4.1 and $\underline{P}_{k+1}^{ij}$, P_k^{ij} are determined from historical records.

The new probability of state vectors can be used to calculate a new mean and standard deviation of achievement in grade k+1 for a particular student type and course of study. The equations for these computations are identical with (8) and (9), except that the zero subscript is replaced by k+1.

5.2 Change in the Number of Dropouts and Truants at Grade k+1

The dropout and truancy relationships of §4.3 and 4.4 can be modified for use in grades following the application of the supplemental program. Both equations require the change in achievement in grade k+1, which is determined in 5.1. In the dropout and truant equations in §4.3 and 4.4, an impedance factor is also used. The change in impedance f_s^{ij} is subsumed in the calculation of the change in achievement, so that only one variable is needed to predict dropouts and truants in years following the application of the supplemental program:

$$\Delta n^{ij}_{k+1,\ \text{dropout}} = \beta^{ij}_{k+1} \quad \Delta A^{ij}_{k+1}, \tag{16}$$

$$\Delta n^{ij}_{k+1,\ \text{truant}} = \emptyset^{ij}_{k+1} \quad \Delta A^{ij}_{k+1}, \tag{17}$$

subject to the non-negativity of the new numbers of dropout and truants.

5.3 Change in the Course of Study Distribution

At one time during the school life a class, the students are required to choose a course of study with an associated curriculum plan. This choice is made by each student type, and may be made at or after the application of the supplemental education program. The course of study distribution is predicated on the assumption that students in the courses of study available can be ranked in decreasing order of expected achievement, i.e. that

$$A^{ij}_k < \bar{A}^{i(j-1)}_k \quad \text{for all } k. \tag{18}$$

It is further assumed that the moments A_k^{ij} and σ_k^{ij} define a normal distribution, and that there is a threshold achievement for each course of study which is determined by a percentage point of the normal distribution with moments defined by the achievement indices for a given student type and each course of study. For example, students with expected achievement between the thresholds for the j^{th} and $(j-1)^{th}$ course of study are assumed to be in the $(j-1)^{th}$ course of study. If the moments of the normally distributed random variable representing student achievement for i at grade k are, for p courses of study,

$$\bar{A}_k^{i\cdot} = \sum_{j=1}^{P} m_k^{iL} A_k^{iL} \Bigg/ \sum_{j=1}^{P} m_k^{iL} \tag{19}$$

and

$$\bar{\sigma}_k^{i} = \left\{ \sum_{j=1}^{P} (m_k^{iL} \sigma_k^{iL})^2 \right\}^{1/2} \Bigg/ \sum_{j=1} m_k^{iL}, \tag{20}$$

then after the application of the supplemental program, these moments change by

$$\Delta \bar{A}_k^{i} = \sum_{j=1}^{P} m_k^{iL} \Delta A_k^{iL} \Bigg/ \sum_{j=1}^{P} m_k^{iL} \tag{21}$$

and

$$\Delta \bar{\sigma}_k^{i} = \left\{ \sum_{j=1}^{P} (m_k^{iL} \Delta \sigma_k^{iL})^2 \right\}^{1/2} \Bigg/ \sum_{j=1}^{P} m_k^{iL}. \tag{22}$$

The course of study selection thresholds do not change, so that the number of students of type i in a given course of study changes if they are to the right of the corresponding threshold changes. The change in the number of students of type i choosing the j^{th} course of study if the choice is made k grades after application of the supplemental program is

$$\Delta m^{ij}_{k} = \left(\sum_{L=1}^{P} m^{iL}_{i}\right)\left(\int_{u^{i}_{j,k}}^{u^{i}_{j-1,k}} \frac{1}{\sqrt{2\pi}} e^{(-1/2)x^{2}} dx\right) - m^{ij}_{k} \tag{23}$$

where

$$u^{i}_{j,k} = \left(\bar{\sigma}^{i}_{k}\, \Phi^{-1}\left(\sum_{L=j+1}^{P} m^{iL}_{k} \Big/ \sum_{L=1}^{P} m^{iL}_{k}\right) - \Delta A^{i}_{k}\right) \Big/ \left(\bar{\sigma}^{i}_{k} + \Delta\bar{\sigma}^{i}_{k}\right), \tag{24}$$

and where $u_{p,k} = -\infty$ and $u_{o,k} = \infty$; and, also where

$$\Phi^{-1}(v) \text{ is given by } \int_{-\infty}^{\Phi^{-1}(v)} \frac{1}{\sqrt{2\pi}} e^{(-1/2)x^{2}} dx = v \tag{25}$$

and equations (18)-(21) can be used to calculate the achievement moments.

Equation (23) states that the change in the number of students of type i in course of study j is related to the area under part of a unit normal distribution. The upper and lower limits of integration which define the area are given by (24); they are chosen so that the achievement threshold values remain constant even though the moments of the distribution change. Students of type i with an expected achievement between the thresholds for the j^{th} and $(j-1)^{th}$ courses of study are assumed to be in the $(j-1)^{th}$ course of study; the proportion of students in that course of study before application of the supplemental program is known and is used to define the threshold achievement for that course of study. After the supplemental program has been applied, the moments of the distribution change. Using the same thresholds and the new distribution, one can compute the proportion of students in each course of study. The restriction that the total population be unchanged is met because

$$\sum_{j=1}^{P} \Delta m^{ij}_{k} = 0 \tag{26}$$

by (19)-(25).

When the course of study selection does occur, it is assumed to occur before truancy, dropout, and net transfer computations are made.

6. Projected Impact on the Community: Present and Future

6.1 The Equality of Educational Opportunity

The equality of educational opportunity can be studied as a function of the difference in expected achievement for two student types at grade k, standardized by the standard error of the difference:

$$d_k^{iL} = (\bar{A}_k^{i} - \bar{A}_k^{L}) \Big/ \sqrt{(\bar{\sigma}_k^{i})^2 + (\bar{\sigma}_k^{L})^2 - 2\,\rho_k^{iL}\,\bar{\sigma}_k^{i}\,\bar{\sigma}_k^{L}}\,, \tag{27}$$

computed before and after the application of a supplemental program. The quantity ρ_k^{iL} represents the correlation between $\bar{A}_k^i$ and $\bar{A}_k^L$ and is set on the basis of empirical findings or judgments. The consequence of under-estimating ρ_k^{iL} is to find equality of educational opportunity when it does not exist. The quantity d_k^{iL} is distributed as a random variable with a t-distribution with $\sum_{j=1}^{p} m_k^{ij} - 1$ degrees of freedom, and can be tested for significance at a level by using the t-distribution. The test should be considered approximate unless ρ_k^{iL} is known. If w pairwise comparisons (26) are to be made, then, to ensure that the significance level is fixed at α overall, each test should be made at the α/w significance level.

6.2 The Number of Graduates

The number of graduates is determined recursively from the balance equation (3) for the largest grade considered, after dropouts, and truants, have been computed in sections 4 and 5.

6.3 Dropout Rate

The unconditional dropout rate is defined as the ratio of students dropping out in grade k to the total number starting grade zero. This measure is useful only if the transfers into and out of the school balance each other. A conditional measure of dropout is defined as the ratio of students in grade k who drop out to the number who started grade k. There is a simple relationship between the conditional and unconditional measure:

if $D_k^{ij} = n_{k,\ \mathrm{dropout}}^{ij} \Big/ m_o^{ij}$, and $c_k^{ij} = n_{k,\ \mathrm{dropout}}^{ij} \Big/ m_{k,}^{ij}$ then $D_k^{ij} = C_k^{ij} \prod_{L=1}^{k-1} (1 - C_L^{ij})$

if net transfers can be neglected.

6.4 Expected Lifetime Earnings

From the achievement predictions, dropout rates, and course of study distribution, it is possible to determine the educational levels of students joining a community, to predict what type of occupation and hence what expected lifetime earnings are to accrue to a student of a given type. This information is then related to the distribution of student types in the community being considered, and an expected average earning potential for a student in that community calculated as a weighted average of the earnings for a student type weighted by the proportion of students of that type.

7. Summary

This summary has attempted only to describe the facets of the educational process which the difference equation model considers, and the final forms of the equations. Much of the motivating sociological theory has been omitted for space considerations, as have the often tricky problems of estimating the parameters and baseline statistics from the historical records.

APPENDIX B

VARIABLE TABLE

The variables listed in this appendix are those used in delineation of and illustrations from the mathematical submodels described in Chapters V - IX.

The Variable List for Chapter V, The Instructional Process Submodel, is divided into sections that closely correspond to those in the chapter.

Service Environment Variables

ΔS is an index of the value of service which the Title I program provides

s_1, s_2, s_3 are coefficients relating ΔQ_s, ΔI_s, and ΔD_s, respectively, to ΔS.

Quality of Service

ΔQ_s is an index of the change in the quality of a school's service environment

P is a yes-no valued variable (written, mathematically as 1 or 0) which is yes if a Title I service program provides a kind of service which is new to the target group; no, otherwise.

F is yes valued if the service program is provided free of any monetary charge to the target group; no valued, otherwise.

q_1', q_2' are coefficients relating P and F respectively to ΔQ_s.

Quantity of Service

Intensity

ΔI_s is an index of the change in the intensity of service which incorporates 5 factors.

Δ #'s of professionals/student Δsq. ft. of space/student Δ\$ spent on materials/student	each of these represents a change caused by a Title I program that is incorporated into ΔI_s.

i_1', i_2', i_3' are coefficients relating the number of professionals, the square feet of space available for service activity, and the cost of service materials to ΔI_s.

i_4', i_5' are additional coefficients which relate, respectively, the conditions of low professional service quality and meager service sufficiency to ΔI_s.

Duration

ΔD_s is an index of the change in time which students spend in service activity.

H_s, H_s' represent the hours per day spent by target group in service activity before and after Title I, respectively.

D_s, D_s' represent the number of days in a week which the target group spends in service activity before and after Title I, respectively.

W_s, W_s' represent the number of weeks in a year in which the target group participates in service activities before and after Title I.

d' is a coefficient relating the changes in service activity time to ΔD_s.

Instructional Environment Variables

ΔC, ΔC_j are repsectively an index of the change in instruction, an index of the change in instruction in a specific, the jth, academic subject.

c_{1j}, c_{2j}, c_{3j} are coefficients relating ΔQ, ΔI, and ΔD, respectively, to ΔC_j.

j is an index for the academic subjects.

Quality of Instruction

ΔQ index of change in quality of instruction

ΔREC index of change in curriculum recency measured in change in years of textbook publication dates

ΔQ_t represents the change in teachers' salaries per teaching hour per student per year

q_1, q_2 coefficients relating curriculum recency and teaching quality, respectively, to ΔQ.

ϕ threshold value linking ΔREC and ΔQ_t to ΔQ.

Quantity of Instruction

Intensity

ΔI an index of the change in the quantity of instruction

Δ #'s of teachers/student Δ #'s of text's/student Δ #'s of desks/student Δ \$ spent on aids/student	each of these represents a change caused by a Title I program that is incorporated into the ΔI index.

i_1, i_2, i_3, i_4 coefficients relating the change in teachers per student, texts per student, desks per student, cost of instructional materials per student to Δ I.

i_5, i_6, i_7 are coefficients which relate the conditions of low teacher competence, scanty instructional material, and large classes to Δ I.

<u>Duration</u>

ΔD — an index of the change in the time to which students are exposed to instruction.

H, H' — represent the hours per day in which the target group is exposed to instruction before and after Title 1, respectively.

D, D' — represent the number of days per week in which the target group is exposed to instruction before and after Title I.

W, W' — represent the weeks per year in which the target group is exposed to instruction before and after Title I.

d — is a coefficient relating the changes in the time spent in exposure to instruction to Δ D.

<u>Student Impedance</u>

Z — a student's "impedance", an index of his resistance to instruction.

\$ — parental income level

E_p — parental educational level

H — measure of degree to which a student is physically or mentally handicapped.

S — index of family solidarity

L_c — the cultural lag--the average amount by which the entire target lags behind national norms in academic achievement

L_s — the student lag--average typical student's gap in basic skills

D_i. — for values of i from 1 to 5, an alternative representation for the first 5 factors of impedance, \$, E_p, H, S, L_c.

z_1, z_2, z_3, z_4 coefficients relating, respectively, parental income

z_5, z_6 parental education, student handicaps, family solidarity, cohort lag and student lag to student impedance.

a a normalization constant relating the D_i's and L_s to Z.

Project-Student Interactions

ΔZ index of the change in student impedance

E_s a measure of the effectiveness of a service program in reducing student impedance

G the target group's grade level

R_1, R_2, R_3 factors which relate Title I projects

R_4, R_5, R_6 qualities to the factors of disadvantageness and thus to ΔZ; these relate, respectively, parental income, parental education, student handicaps, family solidarity, cohort lag, and student lag.

$\left.\begin{array}{l} a \\ z_1, z_2, z_3 \\ z_4, z_5, z_6 \end{array}\right\}$ See under "Student Impedance"

M the maximum amount of change that a project can cause in one year in student impedance.

Z_{max} the upper bound of the index Z.

Z_{min} the lower bound of the index Z.

ΔA the change in academic achievement resulting from a Title I program.

lag the number of grade levels the typical target group member lags behind the grade norm in academic achievement.

F_i the factor in the ΔA computation which accounts for the interaction between Z and ΔC.

F_s the factor in the ΔA computation which accounts for the interaction between Z, ΔZ, and ΔS.

The symbolic variables listed here are those appearing in Chapter VI, The School Flow Submodel. These are those terms actually appearing in the explanation of the school flow model; the terms which are used in the introductory explanation of Markov chains are not included in this list.

Term	
r	the number of subjects in which a student is graded in any one academic term.
i	represents a particular pattern of academic performance expressed as a binary integer.
t	grade level, e.g., $t = 3$ for the third grade.
s, s_i^t	a student in state "s" has a certain combination of academic performance levels distributed across a certain set of academic subjects. More specifically, a student in state s_i^t is in grade t and has the ith pattern of academic performance levels among r subjects.
$p_{ij}(t)$	the probability that a student in state s_i^{t-1} will go to state s_j^t.
P_t	a matrix whose elements are the set of $P_{ij}(t)$ for $1 \leq i \leq r$ and $1 \leq j \leq r$; thus, the matrix contains the probability of passing from any state at grade t-1 to any other state at grade t.
$Z(i)$	is a function equal to the sum, to the base 10, of the digits in the binary integer i.
$\bar{Z}$	is the average number of subjects passed per student in grade t.
$\bar{A}_t$	is the expected avhievement at grade t.
p_t	is a vector whose elements contain the probabilities that a student will be in any given state at a given grade t.
$p_t(s_i)$	is an element in P_t giving the probability for the s_i th state
T	is the number of t's.
σ_t	standard deviation of the number of courses passed.

This section lists the variables found in Chapter VII, The Dropout/ Truancy Submodels.

k	grade level, e.g. $k = 3$ for the third grade
A_k	achievement level at grade k
n_k^d	number of dropouts in grade k
n_k^t	number of truants in grade k
b_1	coefficient relating Δn_k^d to ΔA_{k-1}
b_2	coefficient relating Δn_k^t to ΔA_{k-1}
B_{11}	an expert guess as to the incremental decline in the number of dropouts that a one grade level rise in their achievement could cause.
B_{12}	an expert guess as to the range which should be assigned to B_{11} to be 50% sure that its "true" value is included in the guess.
d_k	dropout rate conditional upon those starting grade k
M_k	number of students who enter grade k
R_k	number of net transfers and deaths during grade k
D_k	dropout rate computed using as starting point the impact grade of Title I program.

This section contains those variables appearing in Chapter VIII, The Course of Study Submodel.

k — grade level e.g., $k = 3$ for the third grade

A_k, A'_k — achievement levels in the kth grade, before and after Title I, respectively.

S_k, S'_k — standard deviation of achievements in the kth grade, before and after Title I, respectively.

p — courses of study index

N — the total number of students to be distributed across all courses.

n_p, n'_p — number of students in the pth course of study before and after Title I, respectively.

m_p — maximum number of students in the pth course of study; such maximums occur because of limited school facilities, etc.

$B_1, \ldots, B_{p-1}$ — course of study thresholds, the average achievement level which a student must obtain to be admitted to a particular course of study.

T_p — the number of students who were not able to be assigned to the pth course of study because of various constraints.

The variables in this section appear in the Index of Equality of Educational Opportunity section of the Community Effects Submodel, Chapter IX.

n	the number of students
i, k	student type indices
j	grade level--e.g., j = 3 for the third grade
$\bar{A}_{ij}$	the expected achievement at grade j for student type i, before Title I
$\bar{A}^*_{ij}$	expected achievement at grade j for student type i, after Title I
σ^2_{ij} or σ^2_{kj}	the variance of achievement distributions for the ith (or kth) student type in grade j
ρ_{ikj}	the correlation between achievement scores between the ith and kth student types in the jth grade
$e_{ik}(j)$	is a measure of the change in educational opportunity for student types i and k from the first to the jth grade
Z	indicates the significance of change in education opportunity as measured by $e_{ik}(j)$

DESIGN FOR AN

ELEMENTARY AND SECONDARY EDUCATION COST-EFFECTIVENESS MODEL

VOLUME II
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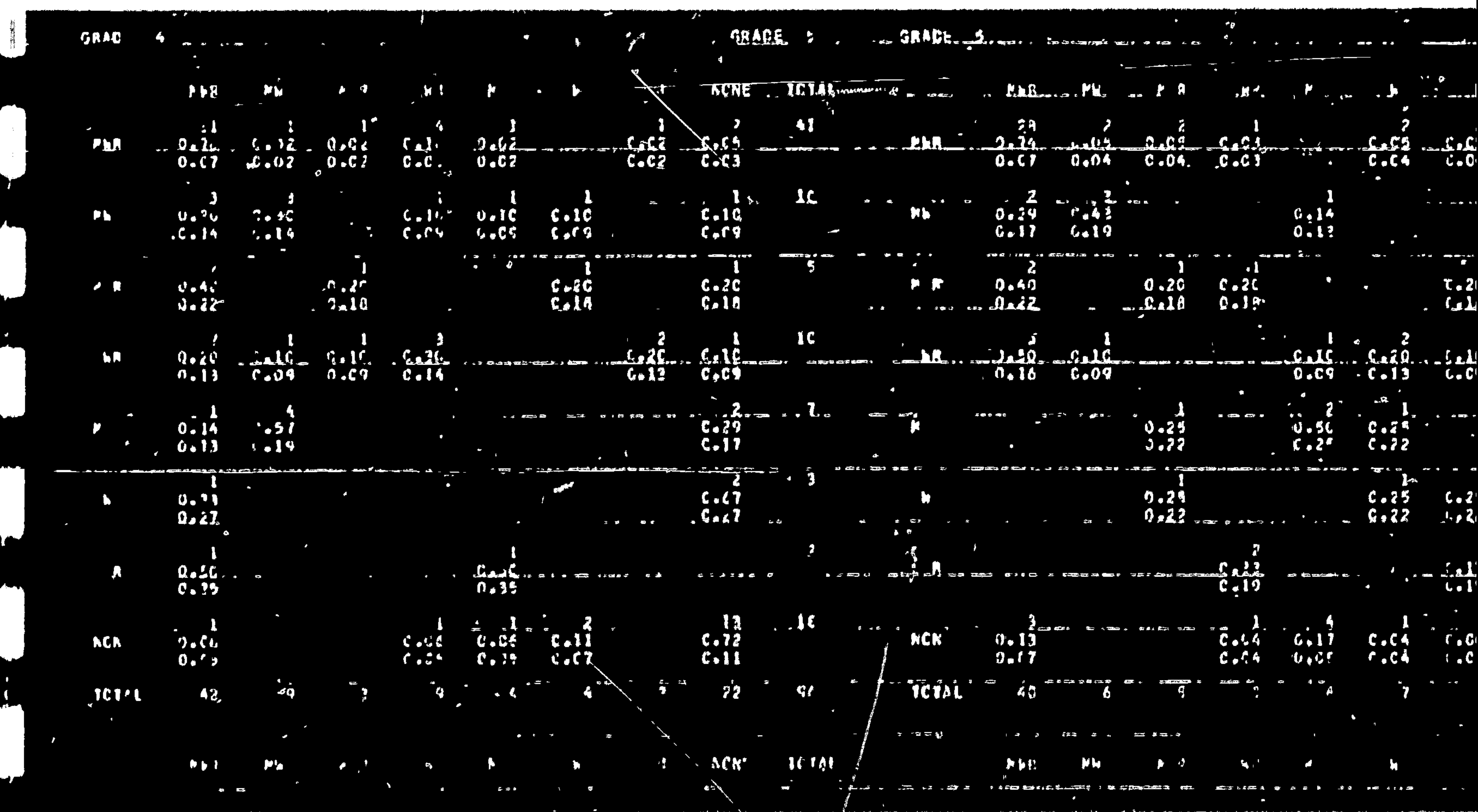

FOR THE

U.S. OFFICE OF EDUCATION

(CONTRACT OEC 1-6-001681-1681)

BY

ABT ASSOCIATES INC.
CAMBRIDGE, MASSACHUSETTS

Division of Operations Analysis
National Center for Educational Statistics

Design For An

ELEMENTARY AND SECONDARY EDUCATION COST-EFFECTIVENESS MODEL

Volume II

The User's Guide

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30 June 1967

ACKNOWLEDGMENTS

The development of the Elementary and Secondary Education Cost-Effectiveness Model was supported by the U.S. Office of Education under Contract OEC 1-6-001681-1681. The work was undertaken between 1 June 1966 and 30 June 1967.

We wish to acknowledge with appreciation the support and guidance of several members of the Office of Education: Dr. David S. Stoller, Director of the Division of Operations Analysis, Mr. Murray Spitzer, Chief, Systems Analysis Branch of the Division of Operations Analysis, Mr. James K. Rocks, Director, Office of Plans and Programs, and Mr. Martin Spickler, formerly Education Specialist, Program Development Branch, Division of Compensatory Education. Dr. Richard Powers and Mr. Michael Kirst, both formerly with the Office of Education, were of great assistance.

Dr. Clark C. Abt directed the Conceptual Design phase of the contract and Mr. Peter S. Miller directed the Mathematical Design phase. The following individuals made major contributions to the model design; Dr. Herbert S. Winokur, Dr. Stephen J. Fitzsimmons, Mr. Stephen A. Bornstein, Mr. James C. Hodder, Mr. Grover C. Gregory, and Mr. Louis J. Cutrona. In addition, valuable work was done by: John Blaxall, Julia Cheever, Charles Fisher, Raymond Glazier, Holly Kinley, Emily Leonard, Diane Macunovitch, Sally Merrill, Keith Moore, Martha Mulloy, Michael Pritchett, Robert Rea, Martha Rosen, Richard Rosen, Lorie Vanderschmidt, and Paul Werbos.

The first volume of this report deals with the model design; the second is a tentative description of the operation of the model, subject to revision when computer programming and testing takes place.

The computer output on the cover is taken from research done with data from Greater Boston schools during the project on the validation of the Markov assumptions of the School Flow Submodel. Shown are transition frequencies from grade 4 to 5 and grade 5 to grade 6 relating various combinations of passing and failing in mathematics, reading, and writing.

Design For An

ELEMENTARY AND SECONDARY EDUCATION

COST-EFFECTIVENESS MODEL

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Table of Contents

CHAPTER I

INTRODUCTION

This volume is intended to depict some of the uses and the requirements of the Office of Education Cost-Effectiveness model, developed by Abt Associates. It should be pointed out that the model discussed in this report has not yet been programmed and put into operation. This model has been developed by Abt Associates to aid in the evaluation of alternative educational projects within school districts proposed under Title I of the Elementary and Secondary Education Act of 1965. The specific intent of the model is to provide data on the probable effects of different projects that might be introduced into a school district. These data are not predictions of the absolute changes that the projects will cause, but are, instead, indicators of the likely effectiveness of the proposed projects relative to each other. The availability of such information to the skilled and experienced educational planner should enhance his ability to select and design projects that will increase the educational opportunity of the disadvantaged child.

In broad terms the model functions in the following way: using information about the current school system, the historic performances of selected student subpopulations, the social, and academic characteristics of the target population, and the Title I proposed changes in the school environment, the model computes likely short-range changes in students' educational achievement and attitude and then extrapolates these effects into longer-range changes in academic achievement, dropout and truancy rates, and certain community effects.

The overall model is divided into four parts, each of which has a separate function; associated with each of these functions is from one to four submodels as indicated below:

FUNCTION	SUBMODEL
INPUT	COST/INPUT
IMMEDIATE TITLE I EFFECTS	INSTRUCTIONAL PROCESS
LONGER-RANGE EFFECTS	SCHOOL FLOW DROPOUT & TRUANCY CALCULATION COURSE OF STUDY SELECTION COMMUNITY EFFECTS
OUTPUT	EFFECTIVENESS OUTPUTS

Because a number of the central concepts of the model's present design are embodied in the Instructional Process (IP) and School Flow Submodel, their operation and theory will be discussed first. The Instructional Process Submodel calculates the changes in academic performance levels caused by a Title I project during the year or years in which it is applied; on the basis of these new levels, the School Flow Submodel extrapolates student achievement out to later years. The model calculates the extrapolated changes relative to its own "baseline". The baseline is generated by running the model with only historical achievement data. Thus, throughout this discussion, "change" refers to those increases or decreases which Title I projects cause relative to baseline results.

The computation done by the Instructional Process Submodel incorporates two main variables: the change in the overall effectiveness of the instructional environment and the change in the students' responsiveness to the learning process. Among children with disadvantaged backgrounds, there is often some hostility toward the school environment and resistance to the learning process. This negative disposition is referred to as impedance toward learning in the model.

The IP uses these two variables in distinguishing between the curriculum and service components of a Title I project. The overall curriculum change variable takes into account the values of descriptors of the changes resulting from a Title I project in instructional quality and quantity. The calculation of change in impedance to learning is accomplished by analyzing a project's service components for their relevance to the individual factors of disadvantage. The model attempts to determine whether a service provided by the Title I project will tend to make up for a background disadvantage of the student. If there is such a service, the student impedance will decline and achievement will improve. Should a project offer no service at all or service that is irrelevant to the disadvantaged students' needs, then any improvement in achievement levels will have to come from the curriculum component of the project.

For example, a program which provides free lunches for children who have a history of low family income is deemed relevant since it tends to offset one of the disadvantages of these children. On the other hand, a program to provide eyeglasses for children who already see well on the average will not be relevant to any of their factors of disadvantage and will not decrease their impedance toward learning.

Summarizing, the Instructional Process Submodel predicts a change in achievement based on the changes in the school's instructional and service environment, calculating this change up to the time when the Title I program no longer is being operated for the particular target group in question. At this point, the longer-range effects portion of the model takes over. The first submodel in this part of the model is the School Flow Submodel, which traces the achievement patterns of the students through the rest of their scholastic career up to the point where they either drop out or graduate from high school. The School Flow Submodel indicates the pattern of achievement for a group of students in any grade based on two factors: the achievement pattern for the group in the last grade that the IP calculated achievements for, and a set of probabilities describing the likelihood of a student moving from a particular pattern in that grade to a particular pattern in the next. For instance, one of the probabilities might be described by saying, "If a student in this particular community or type of community passed English and math in grade 4 but failed science and social studies, the chance that he will pass English, math, and social studies but fail science in grade 5 is .03."

Thus, if there is a Title I program in the third grade, the Instructional Process Submodel will describe the achievement change for students in the third grade. Starting with the fourth grade, the School Flow Submodel will extrapolate, from year to year, the achievement changes for this group of students, keeping track of them all until they either graduate or drop out.

It is likely that the educational analyst will be considerably interested in each of the submodels as a separate entity. Included in this volume in Chapter V is a discussion of the operation of these and of the other submodels as modules which can be separately investigated and tested and their coefficients adjusted.

The achievement changes that the IP and School Flow Submodels compute are key inputs to the remaining submodels in the long range effects portion of the model. These models combine these expected changes with historical information to produce extrapolations of dropout and truancy rates, course of study selection, earnings potential, and the index of educational opportunity. Some of the details of these extrapolations are discussed below.

The Dropout/Truancy Submodel calculates the long-range effects of projected Title I programs on dropout and truancy rates. At the end of each simulated school year this submodel determines the number of dropouts and the average truancy rate for that year. The truancy rate is recorded so that it may be reported and the dropouts are removed from the group of students whose school performance is to be extrapolated through the following years. The point at which students drop out is recorded and used both as an output and as data for the calculation of potential lifetime earnings.

The Course of Study Submodel uses the projected achievement changes to calculate the changes that will occur in the numbers of target group members who could be expected to be in each type of academic course in secondary school. That is, the submodel determines how many of the students will go into the various courses of study, where available.

Briefly, the procedure by which this submodel determines the changes in patterns of course of study selection is to calculate the changes in the mean values of achievement for students at the point in their school careers at which they select a course of study. Based on the upward shift in the distribution of achievement for the students, the model makes more students eligible for those courses of study for which a higher achievement mean is required. The course of study selected by the students as a result of the change in their achievement means will depend upon their backgrounds and the kinds of factors described in the Instructional Process Submodel.

The outputs of the preceding submodels are presented to the user for analysis, but they are also needed as data for the Community Effects Submodel. There are two kinds of outputs to be derived from this submodel. The first kind of output deals with the expected or potential lifetime earnings of the students, and the change in these figures as a result of the proposed Title I programs. A student's potential lifetime earnings are calculated on the basis of three important variables: 1) whether he drops out of school or not, and if he does, when he does; 2) the course of study he has selected in school, if the point of specialization has been reached; and 3) for graduates, their achievement levels upon graduation. The second kind of Community Effects output is an indicator which describes Coleman's concept, "the equality of educational opportunity." That is, the association of student performance with student background is measured. To the degree that such an association is not present, to that degree there is said to be equality of educational opportunity.

The remaining submodels, the Cost/Input and Effectiveness Outputs, are concerned with interfaces between the model and its users.

The input portion of the model is a straightforward data input and error checking procedure which serves to construct the data-base for the model. It takes as input punched cards with data describing the particular school or school district, the student population, and the community as a whole. It determines whether cost subtotals add up to give the total described on the input cards; in addition, it checks for seemingly false implications among the data. For example, should a project be described as being relevant to the basic health needs of the target group and the Cost/Input Submodel cannot find any budget entries in the categories that are relevant to these needs, it will print out a note indicating the inconsistency and ask for confirmation or correction of this information. As well as reports of such errors or inconsistencies, the model provides reports on the proposed budget to facilitate cross-project cost comparisons and to allow additional verification of these data. After requesting user clarification of ambiguous or incorrect information, the program will make up a data base tape for use by the submodels described above during the actual simulation of the effects of the Title I program. Detailed information on the data needs of the model may be found in Chapter III of this volume.

The last submodel to be discussed is the Effectiveness Outputs Submodel, which will provide output for study and analysis by the decision-makers involved in evaluating proposed projects. Because the model design has been aimed at developing an aid to decision-making, the output from the model must be in a form which its users can understand and work with. The output shows the effects of only a single particular program so that the general educational areas in which the program will have impact can be seen, and so that it can be determined whether the program will have beneficial or deleterious effects on the students in the school in question. More important, however, is the function of comparatively evaluating alternative proposed projects in a particular school or school district so that they may be readily analyzed by Title I decision-makers. A discussion of these outputs is presented in Chapter II of this volume.

Although the Office of Education Cost-Effectiveness Model has not yet programmed and operated on a computer, its development has given rise to information about its probable use, requirements, and organization. This tentative information is found in this volume. For detail on the design of the model, Volume I should be consulted.

A brief model profile is given on the next page as a summary for readers of this volume.

A Brief Profile of the OECE Model

The Model Will:	Function	The Model Won't:
Deal with groups of students Deal with students below national norms Indicate changes in student group achievement	Students and student change	Deal with individuals Evaluate programs to raise achievement of students above national norms
Indicate changes in rate and year of dropouts Indicate increased or decreased numbers of high school graduates Indicate changes in course of study selection where applicable	School change	Simulate changes in the administrative policy in a school district
Indicate changes in potential life-time earnings Indicate changes in equality of educational opportunity	Community change	Simulate change in the home as a result of Title I
Compare the cost-effectiveness of proposed Title I and other educational improvement projects within a school district Aid decision-makers Determine relative effectiveness of proposed Title I programs	Evaluation	Compare proposed Title I projects across districts Make decisions Determine absolute effectiveness of proposed Title I programs
Need commonly available data	Data input	Give results more precise than the input data

CHAPTER II

USE OF THE OUTPUTS

The outputs of the OECE simulation describe the changes in the students and their environment resulting from the introduction of a Title I program into the school or school district being simulated. The output formats presently designed are of several sorts.

The Summary Output

The overall summary shows the Title I program impacts on the school and community. Average Achievements, Values for the Index of Impedance to Instruction, Number of Dropouts, and Number of Graduates are listed under the heading School Impacts (Figure 1). These are defined as:

1. The Average Achievement is the average of a student's grade levels in all subjects. It is given at the target grade and at the twelfth grade. (If the target group spans more than one grade, the average is given for the highest grade.)

2. The Index of Impedance to Instruction is a measure of the average incidence within a student type of certain characteristics thought to be detrimental to the student's receptivity to instruction. The index values range from one to ten; high values indicating that the student has many environmental characteristics of disadvantage, low values indicating fewer environmental disadvantages.

3. The Number of Dropouts is the total number of students from the target group expected to leave school before graduation.

4. The Number of Graduates is the total number of students from the target group expected to graduate.

Equality of Educational Opportunity and Expected Average Lifetime Earnings are listed under the heading:

COMMUNITY IMPACTS

The Index of Educational Opportunity measures the degree to which students' educational achievement is dependent upon their socio-economic background. (A fuller discussion of this index is given in Chapter IX of Volume I). The index in the summary is scaled so that if the condition of perfect equality is met, the index equals one; if perfect inequality occurs, the index equals zero.

The Expected Average Lifetime Earnings show the projected earned income for an average student of a particular type.

Achievements

In addition to the information in the overall summary, more detailed data is provided about academic achievement (Figure 2). Achievements are given in grade levels; e.g., a student reading at the beginning fourth grade level has an achievement level of 4.0 in reading regardless of the grade he is actually in. These levels are shown for the average student for each student type, for twelve grades, in up to six academic subjects.

Dropouts and Attendance

Outputs about the number of dropouts and the attendance rate are provided in a graphical format (Figure 3). These graphs give a twelve grade breadown for the entire school population; i.e., the individual figures about dropouts and attendance for each grade are not disaggregated by student type. The attendance percentage is based upon the total student days, which equals the number of students multiplied by the number of school days.

SUMMARY OUTPUT

U.S.O.E. COST-EFFECTIVENESS MODEL

COMMUNITY:	FERNDALE MASS	PROJECT TYPE:	REMEDIAL READING
TARGET POPULATION:	G2-3 SCHOOL B	ANNUAL COST:	85000

SCHOOL IMPACTS

	STUDENT TYPE	AVERAGE ACHIEVEMENT TGT-G	AVERAGE ACHIEVEMENT G-12	INDEX OF IMPEDANCE TO INSTR	NUMBER OF DROPOUTS	NUMBER OF GRADUATES
BEFORE PROJECT, YEAR: 1965	1	1.2	8.6	8.6	20	28
	2	2.0	10.3	8.4	16	31
	3	1.4	7.9	8.0	21	27
	4	3.2	12.0	5.6	9	46
AFTER PROJECT, YEAR: 1967	1	1.8	10.2	7.3	16	32
	2	2.6	11.0	6.9	12	35
	3	2.4	11.2	5.8	17	31
	4	3.2	12.0	5.6	8	47

COMMUNITY IMPACTS

EQUALITY OF EDUCATIONAL OPPORTUNITY

	BEFORE PROJECT, YEAR: 1965	AFTER PROJECT, YEAR: 1967
COMBINED	.40	.50
BY INCOME GROUPS	.35	.40
BY ETHNIC GROUPS	.18	.27

EXPECTED AVERAGE LIFETIME EARNINGS

STUDENT TYPE	BEFORE PROJECT, YEAR: 1965	AFTER PROJECT, YEAR: 1967
1	$ 200000	$ 275000
2	$ 300000	$ 400000
3	$ 325000	$ 400000
4	$ 450000	$ 500000

STUDENT TYPES

1 NON-WHITES UNDER 2000 INCOME 3 WHITES UNDER 2000 INCOME
2 NON-WHITES OVER 2000 INCOME 4 WHITES OVER 2000 INCOME

ACHIEVEMENT OUTPUTS
BY GRADE, SUBJECTS, AND POPULATION TYPES

COMMUNITY: FERNDALE MASS — PROJECT TYPE: REMEDIAL READING

TARGET POPULATION: G2-3 SCHOOL B — ANNUAL COST: 85000

GRADE LEVELS IN LANGUAGE

	STUDENT TYPE	1	2	3	4	5	6	7	8	9	10	11	12
BEFORE	1	.6	1.1	1.6	2.3	3.0	3.8	4.5	5.2	7.0	7.6	8.2	8.9
PROJCT	2	.8	1.2	1.9	2.9	3.4	4.5	5.1	6.0	7.7	8.4	9.3	10.0
YEAR:	3	.8	1.3	2.0	3.1	3.7	4.9	5.8	6.6	8.6	9.2	9.9	10.9
1965	4	1.2	2.1	2.9	4.0	5.0	6.2	7.1	8.0	9.3	10.2	11.0	12.0
AFTER	1	.6	1.4	2.9	3.0	3.9	5.8	6.7	7.6	8.5	9.4	10.3	11.0
PROJCT	2	.8	1.5	3.0	4.0	5.0	6.0	6.9	7.9	8.9	9.9	10.9	11.6
YEAR:	3	.8	1.7	3.1	4.0	5.2	6.2	7.1	8.0	9.0	10.0	11.0	12.0
1968	4	1.2	2.1	2.9	4.0	5.0	6.2	7.1	8.0	9.3	10.2	11.0	12.0

GRADE LEVELS IN MATHEMATICS

	STUDENT TYPE	1	2	3	4	5	6	7	8	9	10	11	12
BEFORE	1	.5	1.1	1.8	2.3	3.0	3.6	4.4	5.0	5.8	6.3	7.0	7.7
PROJCT	2	.8	1.3	2.2	2.9	4.0	4.6	5.5	6.1	7.0	8.0	8.1	8.8
YEAR:	3	.9	1.5	2.7	3.1	4.1	5.0	6.7	6.6	7.2	8.0	8.1	8.8
1965	4	1.0	2.0	2.9	3.9	5.0	6.2	7.1	8.0	9.1	10.0	11.1	12.0
AFTER	1	.5	1.3	2.2	3.0	4.0	4.6	5.4	6.0	6.7	7.2	8.0	8.8
PROJCT	2	.8	1.8	2.9	3.9	5.0	5.6	6.5	7.1	8.1	8.4	8.5	9.0
YEAR:	3	.9	2.0	3.0	4.1	5.0	6.0	7.0	8.0	8.8	9.0	9.[illegible]	9.4
1968	4	1.0	2.1	3.0	4.2	5.1	6.0	7.0	8.0	9.0	10.0	11.0	12.0

GRADE LEVELS IN SCIENCE

	STUDENT TYPE	1	2	3	4	5	6	7	8	9	10	11	12
BEFORE	1	.6	1.4	2.9	3.0	3.9	5.8	6.7	7.6	8.5	9.4	10.3	11.0
PROJCT	2	.8	1.5	3.0	4.0	5.0	6.0	6.9	7.9	8.9	9.9	10.9	11.6
YEAR:	3	.8	1.7	3.1	4.0	5.2	6.2	7.1	8.0	9.0	10.0	11.0	12.0
1965	4	1.2	2.1	2.9	4.0	5.0	6.2	7.1	8.0	9.3	10.2	11.0	12.0
AFTER	1	.6	1.1	1.6	2.3	3.0	3.8	4.5	5.2	7.0	7.6	8.2	8.9
PROJCT	2	.8	1.2	1.9	2.9	3.4	4.5	5.1	6.0	7.7	8.4	9.3	10.0
YEAR:	3	.8	1.3	2.0	3.1	3.7	4.9	5.8	6.6	8.6	9.2	9.9	10.9
1968	4	1.2	2.1	2.9	4.0	5.0	6.2	7.1	8.0	9.3	10.2	11.0	12.0

STUDENT TYPES: 1-NONWHITES, LESS THAN 2000 3-WHITES, LESS THAN 2000
2-NONWHITES, MORE THAN 2000 4-WHITES, MORE THAN 2000

FIGURE 2

ATTENDANCE AND DROPOUT OUTPUTS

COMMUNITY: FERNDALE MASS

PROJECT TYPE: REMEDIAL READING

TARGET POPULATION: G2-3 SCHOOL B

ANNUAL COST: 85000

PER CENT ATTENDANCE BEFORE PROJECT YEAR: 1965

95-100												
90- 94		90	90		93	92	94					
85- 89	85							89				
80- 84				83					81		80	
75- 79										78		76
70- 74												
65- 69												
60- 64												
55- 59												
50- 54												
0- 49												
GRADE	1	2	3	4	5	6	7	8	9	10	11	12

PER CENT ATTENDANCE AFTER PROJECT YEAR: 1967

95-100							96					
90- 94		90	90		93	91		90				
85- 89	85			85					87	85		
80- 84											80	84
75- 79												
70- 74												
65- 69												
60- 64												
55- 59												
50- 54												
0- 49												
GRADE	1	2	3	4	5	6	7	8	9	10	11	12

NUMBER OF DROPOUTS PER GRADE BEFORE PROJECT YEAR: 1965

45- 50												
40- 44												
35- 39												
30- 34												
25- 29												
20- 24											20	
15- 19												16
10- 14										14		
5- 9								6	7			
0- 4	0	0	0	0	0	2	0					
GRADE	1	2	3	4	5	6	7	8	9	10	11	12

NUMBER OF DROPOUTS PER GRADE AFTER PROJECT YEAR: 1967

45- 50												
40- 44												
35- 39												
30- 34												
25- 29												
20- 24												
15- 19												
10- 14												
5- 9									5	8	9	7
0- 4	0	0	0	0	0	0	1	2				
GRADE	1	2	3	4	5	6	7	8	9	10	11	12

FIGURE 3

There are <u>three basic uses</u> of the outputs from the simulation. The first and most obvious use is that of program evaluation, where the computer output is used as an aid to decision-making. The second use is that of checking the design and variable settings of the model. The third use is for the redesign and new design of computer outputs which will better accomplish the first two tasks.

The evaluation function is carried out through the comparison of the values of the variables shown on the output forms for different potential Title I programs. These data are in a form readily usable by educational adminstrators and experts, and the comparison of several potential Title I programs should be fairly straightforward. The variables described above are present, and the different programs will be likely to have differential effects with respect to these variables, so that one program might raise achievement significantly in a particular subject area, while another program might raise achievement slightly in all of the available subjects.

There was some thought given, at the beginning of the design project, to the development of a system whereby the various changes in the different variables might be assigned values so that each program might then be characterized by a single value number. This value number would be the total of the values for the various changes. It was decided, after consideration of the problem, that this form of benefit calculation would be inappropriate for two reasons. First, the determination of values for the changes in variables is not a simple problem. It is highly probable that the value of a change in one variable is not independent of changes in other variables. Secondly, there is no opportunity for educational experts to use their experience and expertise when dealing with a single number; the computer, using a simple mathematical model (simple when compared with all the complexities of reality), cannot begin to bring to bear the kind of intuition and experience which the analyst can draw upon when making a value judgment.

It was therefore decided to give the decision-maker direct access to the computed expectations of the model (in terms of results of

Title I projects) and the associated cost figures, and thus enable him to make his own determination of the relative values of the overall projects based on his experience and judgment.

The second main use of the simulation outputs is that of checking the parameter settings and logical design of the model. When the results of the simulation seem to disagree consistently with the user's judgment as to the likely effects of the potential program being simulated, an investigation should be made. When results from the field on an actual program are available, they may be used for comparison purposes, with the realization that the communities in which the two similar programs were attempted or simulated were, of course, different. In addition, the literature may be searched for references to similar projects and their effects, the judgments of other experts may be consulted, and research projects in that area may be found relevant.

Based on this type of investigation, the user may decide to make no changes in the model, or he may wish to change the setting of one or more parameters, or he may wish to change the model's logic. The change may be checked by modular operation of the submodel in question (see Chapter V). If it is found to give better results than the previous setting or design, it should be retained in the model.

When dealing with an area as unexplored as that of large-scale simulation of the educational process, we must be careful to allow room in the design for such changes as those described above. This has been accomplished in the present model by 1) structuring the outputs so that the user sees the results of a simulation run in a familiar form and thus can detect model results which disagree with his intuition, 2) by designing the model in modular way so that whole parts may be removed and replaced, 3) by using parameters in such a way that their values may be changed easily and that their effects are clear, and 4) by planning to program the model in a widely known and available and easily used computer language, Fortran IV.

Routine use of the simulation may point up deficiences in the output format. Since the simulation itself is only as good as the information it conveys, suggested revisions of the present output presentation will be as important as suggested revisions of the model itself. A simulation output is supposed to give the user the information he needs for decision-making in a form which best suits his needs and which can best be understood by him. At times, the designers of simulations assume that if all the important variables are listed in the output, the format of the output does not matter. An example of this sort of thinking is the usual standard regression package output; all the variables are present, but a user who is anything other than expert cannot make very good use of the data.

A test of the sufficiency of the present outputs, which were developed in concert with members of the Title I group at the Office of Education, will be: are the users of the outputs, in their study of the data presented therein, constructing new graphs, matrices, tables, etc. to aid their evaluation? If this is the case, and the auxilliary aids being used are of a standard form, then they should be programmed and added to the library of available outputs.

These then are the three basic uses of the simulation outputs program evaluation, parameter setting and logic redesign, and output format redesign.

CHAPTER III

INPUT DATA REQUIREMENTS OF THE MODEL

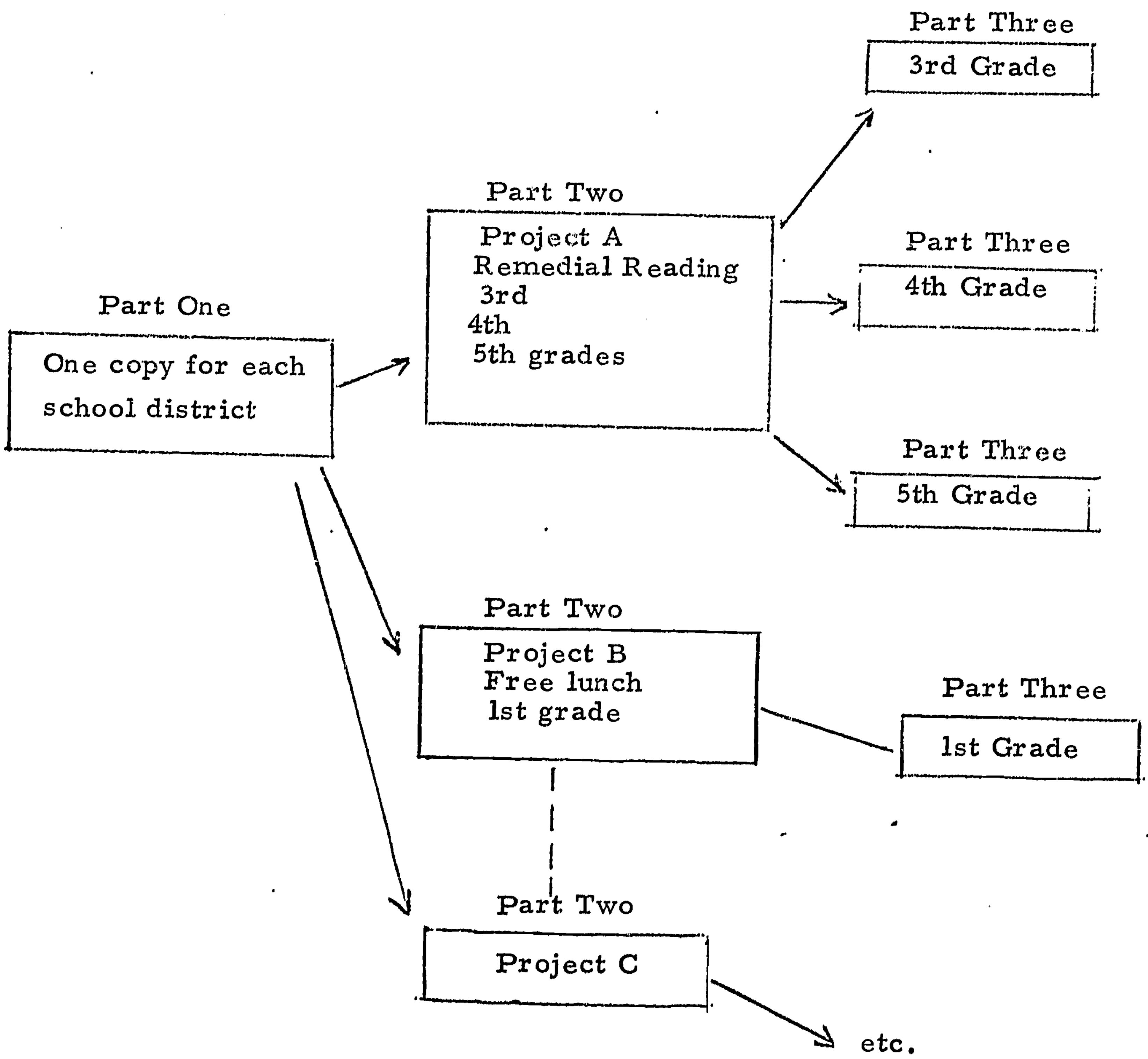
The overall model needs three kinds of information derived from the proposal request questionnaires: information describing the characteristics of the student, the characteristics of the school, and the specifics of the project. These three sets of data are retained for use by the computer. The information needed will be provided by the requesting party on a questionnaire form accompanying the standard Title I request form.

This questionnaire consists of three major parts, each concerned with one of the types of data needed to evaluate projects proposed under the provisions of Title I of the Elementary and Secondary Education Act of 1965. The first part is a set of questions about the general characteristics of the school district and its student population. In general only one copy of this section need be completed regardless of the number of proposed projects. The second and third parts contain questions about the details of the proposed projects and the characteristics of the student body subpopulations (or target groups) toward whom the projects are to be directed. For each proposed project a Part II form must be completed and for each unique subpopulation a Part III form must be completed. Figure I illustrates this procedure.

FIGURE I

Proposal Request Questionnaire (Example)

Part One	Part Two	Part Three
General Characteristics of the School and the Student Population	Details of the proposal Projects	Student body characteristics



Since the thrust of the ESEA is to improve the education of the disadvantaged child, evaluation of proposed projects must necessarily take into account known factors of disadvantage of the projects' target groups. Thus, a large proportion of the data to be entered in this questionnaire is concerned with the socio-economic backgrounds of the students and how these backgrounds are related to academic performance. Throughout the questionnaire, information is requested about four socio-economic types of students. Student types are defined so that we may separate those groups which we expect have significantly different backgrounds on the average, or which we expect may show differential change as a result of Title I programs. The types presently used in the model are:

<u>Type 1</u>, non-white students from families with an annual income less than $2,000.

<u>Type 2</u>, non-white students from families with an annual income greater than $2,000.

<u>Type 3</u>, white students from families with an annual income less than $2,000.

<u>Type 4</u>, white students from families with an annual income more than $2,000.

If precise data are not available for these student types, then whenever possible, reasonable approximations should be made. Different group definitions may be used where applicable, depending on the community in question.

A project will have somewhat different effects on different students depending not only upon their socio-economic background, but also upon their school experience and age. To evaluate a project, these latter factors must be taken into account; this is done by describing the group at which the project is aimed in terms of the typical or average "target group" member. A "target group" is defined as a student body subpopulation which has a unique combination of school environment and grade. Thus, a school subpopulation in which all the members attended the same school but were in two different grades, e.g., third and fourth graders, constitute two "target groups". A Part III form must be completed for each of these groups.

If a project is aimed at two or more different target groups, it may be necessary for the purposes of this questionnaire only to treat that project as two or more different projects. This is necessary when the data concerned with the effects of the project on the target group's environment is not the same for the different target groups. If these data are different, a Part II should be completed for each different data set, with the appropriate *pro rata* adjustments made on costs, etc. Each of the three parts of the questionnaire will now be discussed in detail--Figure 2 illustrates the organizations of the questionnaire.

General Student Body and School Characteristics (Questionnaire--Part One)

This part of the questionnaire asks for seven kinds of numerical data for each of the school grades and for each of the four types of students. The first three questions deal with the present number of students, the number of truants, and the number of dropouts. We assume that these data are easily obtainable in total. We hope that the school administrator can estimate the numbers for each type of student. Many of these numbers can be left out (e.g., dropouts, grade 2, all student types) since they are negligible.

The last four questions pertain to course of study selections. In some school systems these questions are not relevant and can be omitted. We allow the requestor to specify up to four kinds of secondary courses of study, e.g., college preparatory, general, commercial, and vocational. Some school systems may have no courses of study as such, some have fewer than four, some may have more or give them different names. Our model assumes that the student body is separated into at most four courses and that within each course numbers can be given for each of the four student types.

FIGURE 2

ORGANIZATION OF THE QUESTIONNAIRE

PART ONE: General Student Body and School Characteristics (Seven Questions)

1. Question # 1 asks for the number of students by year and student type
   Question # 2 asks for the number of truants by year and student type.
   Question # 3 asks for the number of dropouts by year and student type.
2. Questions # 4-7 pertain to the course of study (numbers of students and the achievement levels in each of four courses of study.)
3. All of the questions ask for information categorized by grade and by student type.

   Model Use: Dropout, truancy, course of study routines.

PART TWO: The Title I Project Characteristics (Four Kinds of Questions)

1. The category best describing the project (free lunch, TV lecture, etc.)
2. Project impact on school instruction. (Changes in numbers of teachers, costs, etc., by academic subject area.)
3. Project impact on school services. (Changes in numbers of professionals, costs, etc.)
4. Project cost by category (administration, instruction, attendance, services, etc.)

   Model Use: Instructional Process routine.

PART THREE: The Target Group (Three Kinds of Questions)

1. Student background (parent education, family income, etc.)
2. Student achievement (by subject area)
3. Student classroom (by subject area)

   Model Use: Instructional Process and School Flow Routines

Questions four through six in Part I require the school administrator to give the grade in which the student is assigned to a course of study, the numbers of students in each course, and the maximum number of students that can be accomodated in each course. This latter question implies that the physical layout of facilities and numbers of available staff to teach each course may be limited.

Question number seven requires estimating the average achievement for each of the four types of students. We expect that achievement will be expressed in grade years and months (with a ten-month school year), so if the average achievement level at the end of the seventh grade were 6.8, this would be interpreted as sixth grade, 8th month. These achievements should be estimated in relation to national norms where possible.

The important fact to remember is that a proposed project which deals with several different grades or students from different schools must be broken up into sub-projects--one for each set of students. This distinction is necessary because of the possible differential effects of the program on the different groups.

<u>The Title I Project Characteristics</u> (Questionnaire--Part Two)

The second part of the questionnaire asks for qualitative and quantitative information in order to describe the Title I project, namely, a qualitative selection, from a list of five, of the category which best describes the proposed project; and the quantitative impacts that the project will make on instruction and school service. Each of these sets of information will be explained in more detail.

The administrator is asked to choose, from the following list, the category which best describes the proposed sub-project:

1. Does the project supplement the students' need for basic necessities such as food and clothing? E.g., a free lunch program.

2. Does the project enhance the students' academic program by adding or strengthening subjects? E.g., a TV lecture series.

3. Does the project broaden the students' cultural exposure? E.g., field trips, inter-school attendance, or the like.

4. Does the project supply medical, dental, psychological, or therapeutic services?

5. Does the project provide remedial academic instruction?

Any or all of these five categories may be offered as part of the proposed project. The purpose of the questions is to determine the degree of match between the project offerings and the needs of the students.

The administrator is asked to provide quantitative data describing the impact that the proposed Title I sub-project has on the school in terms of changes in either numbers of teachers, desks, or updated curriculum materials, and the like. We have divided the project impact questions into an instructional section and a school service section. Within the instructional part we have further subdivided the questions into academic subject areas. We are interested in the changes in numbers of teachers or desks with respect to a particular elementary school subject such as mathematics, reading, writing, or spelling while for the secondary school, we are interested in the changes in numbers of teachers or desks for subjects such as mathematics, English, social studies and science.

In section four of Part II of the questionnaire, the administrator is asked to provide cost data for each of his sub-projects. The categories for these costs are the same as those asked for in Form OE 4305 items 8A and 8B.

In summary, Part II of the questionnaire, dealing with the Title I project, is concerned with determining the characteristics of the project which are immediately relevant to the student's disadvantage.

The Target Group (Questionnaire--Part Three)

In Part III, questions are asked pertaining, first, to the students' background, next, their achievement, and finally, their classroom. Three questions are addressed to the students' background, as to whether the average parents have less than a secondary education, whether the family life is disrupted, i.e., one or both parents absent in the home and whether the students are physical ly or mentally handicapped. These questions set the stage for determining some of the characteristics of the students' disadvantage and are asked separately for each type of student.

We characterize the remainder of the indication of students' disadvantage in the second section of questions, by their academic performance in certain subject areas. The questions ask the administrator to list his estimate of the numbers of students in each of the four target groups who perform satisfactorily in some or all of the subjects; we ask these questions for each combination of subjects. For example, we are interested in how many elementary students did well only in reading and writing, implying that they did poorly in mathematics and spelling. By poorly, we mean well below the averages established for this local school group, in the eyes of the administrator.

The third set of questions pertains to the classroom and specifically to the same four subject areas treated previously. We need to know:

1. Whether or not the teachers' mastery of the subject is as complete as desired.

2. Whether or not the classrooms are large enough and materials in as great a supply as desired.

3. Whether or not there are fewer teachers than needed for desirable work loads

4. Whether or not there are more than 30 students to a classroom.

And in terms of the school services provided:

5. Whether or not the quality of the professionals providing service is as high as desired and

6. Whether or not non-classroom areas are large enough and service materials in as great a supply as desired.

All of these questions determine the degree of match between the proposed program, the students' needs, and the school classroom needs.

Summary

The three parts of the questionnaire have been discussed in terms of information needs of the model and the requirement that the school administrator provide characteristics of his school district, characteristics of his proposed Title I project, and, finally, characteristics about the disadvantaged child and his classroom. The questionnaire provides quantitative and qualitative information to measure the degree of match between the needs of the disadvantaged students and the specific parts of the projects, as well as delineation of academic variables.

A preliminary version of the questionnaire follows.

PROPOSED TITLE I PROJECT QUESTIONNAIRE

____

School Name

____

School District

______________ ______________ ______________

City County State

QUESTIONNAIRE
PART ONE

The General Student Body and School Characteristics

C. 6 The Target Group's School Environment

Instructional Environment

Target Group Grade Level: elementary / secondary	SUBJECT: Reading / English	Composition / Social Studies	Spelling / Science	Math
Answer each question (Yes or No):				
Is the teachers' mastery of the subject as complete as desired?				
Are classrooms as roomy and materials in as great supply as desired?				
Are there fewer teachers than needed for desirable work loads?				
Are there more than 30 students per class?				

General Student Body Characteristics

A.1 Present Number of Students Per Grade

		Grade	1	2	3	4	5	6	7	8	9	10	11	12	Total
Student Type	1														
	2														
	3														
	4														
		Total													

A.2 Number of Truants Per Grade[1]
(Leave Blank if Number is zero or negligible)

		Grade	1	2	3	4	5	6	7	8	9	10	11	12	Total
Student Type	1														
	2														
	3														
	4														
		Total													

A.3 Number of Dropouts Per Grade[1]
(If the number of dropouts for any grade is less than 2% of the grade's population, the column for that grade may be left blank)

		Grade	1	2	3	4	5	6	7	8	9	10	11	12	Total
Student Type	1														
	2														
	3														
	4														
		Total													

[1] If these statistics are not available by student type, please enter the total by grade, otherwise the totals should be left blank.

A.4 Grade Immediately After Which Course of Study is Usually Chosen
(If school system does not have courses of study, enter a zero and skip remainder of Part A)

A.5 Current Number of Students in Each Course of Study

Courses of Study (Titles)	Student Type 1	2	3	4

Courses of Study (Titles)	Maximum Number of Students that Can be Accomodated by the Personnel Facilities Available for Each Course

A.7 Average Achievement in the Grade Preceding Course of Study Selection

	Student Type 1	2	3	4
Of the Top 25% of Students				
Of the Top 50% of Students				
Of the Top 75% of Students				

(Average achievement is expressed in years and months; e.g., 6.8 means 6th grade, 8th month)

QUESTIONNAIRE
PART TWO

The Title I Project Characteristics

Project Characteristics

B. 1 Project Name ____________________

B. 2 Assign this project an arbitrarily chosen identification number from 1 to 99 and enter this number in the line below. Each project should be assigned a different number. ☐

B. 3 Check the Project Descriptions below which most nearly describe this project:

The project supplements the students' basic necessities such as food and clothing. ☐

The project enhances the students' academic program by adding or strengthening subjects. ☐

The project broadens the students' cultural exposure through field trips, inter-school attendance, etc. ☐

The project supplies medical, dental, psychological, or therapeutic services. ☐

The project provides remedial academic instruction. ☐

B.4 Section B.4 is concerned with the changes that this project will have on its target group's instructional environment. If the project will cause measurable changes in the environmental factors in column 1, please enter the size of the increase or decrease under the most appropriate subject in column 2. (Decreases should be enclosed in parentheses.)

1 Environmental Factors	2 Elementary Target Grade / Secondary Target Grade	Math / Math	Reading / English	Writing / Social Studies	Spelling / Science
Number of Teachers					
Number of Texts					
Number of Desks					
Available Classroom area		sq. ft.	sq. ft.	sq. ft.	sq. ft.
Number of Years texts are updated		yrs.	yrs.	yrs.	yrs.
Student Time in instruction					
Hours/Day		hrs.	hrs.	hrs.	hrs.
Days/Week		days	days	days	days
Weeks/Year		weeks	weeks	weeks	weeks
Teachers' Salaries	$		$	$	$
Cost of Curriculum supplies and equipment	$		$	$	$

B.5 Section B.5 is concerned with the changes that this project will have on its target group's service environment. If the project will cause measurable changes in the service environment factors in column 1 below, please enter the amount of the increase or decrease in column 2. (Decreases should be enclosed in parentheses.)

1 Service Factors	2 Increases or Decreases
Number of Service Professionals	
Area Allotted for Service Activities	sq. ft.
Hours of Service Activity/Day	hrs.
Days of Service Activity/Week	days
Weeks of Service Activity/Year	weeks
Cost of Service Supplies and Equipment	$

B.6 Please indicate that amount of the projects cost which can be attributed to providng services or materials to the target group in each of the following categories.

	Dollar Cost
Administration	
Instruction	
Attendance Services	
Health Services	
Pupil Transportation Services	
Operation of Plant	
Maintenance of Plant	
Fixed Charges	
Food Services	
Student Body Activities	
Community Services	
Remodeling (Less than $2000)	
Equipment	
Professional Services for Site	
Sites and Site Additions	
Improvements to Sites	
Professional Services for Building	
Remodeling ($2000 or more)	
Equipment (obtained as part of construction)	
Total	

QUESTIONNAIRE

PART THREE

B

The Target Group's Social and Academic Characteristics and School Environment

One copy of this section must be completed for each target group

Target Group Characteristics

A copy of this section should be completed for each target group.

C. 1 Target Group Grade ☐

C. 2 Assign this target group an arbitrarily chosen identification number from 1000 to 1999. Each target group should be assigned a different number. ☐

C. 3 Answer yes or no to each question below about the typical target group student's background.

	Student Type			
	1	2	3	4
Do the student's parents have less than a high school education?				
Is the average family disrupted? (E. g. father absent, mother working fulltime, etc.)				
Is the average student physically or mentally handicapped?				

Complete section C.4 if target group is at an elementary grade, section C.5 if target group is at a secondary school grade.

C.4 Target Group Characteristics

Indicate the number of target group students of each type who have the indicated patterns of academic performance levels. (If neccessary, use estimates.)

Pattern for elementary school target grades	Student Type				
	1	2	3	4	Total
1. Did well in all subjects					
2. Did well only in math					
3. Did well only in reading					
4. Did well only in writing					
5. Did well only in spelling					
6. Did well only in math and reading					
7. Did well only in math and writing					
8. Did well only in math and spelling					
9. Did well only in reading and writing					
10. Did well only in reading and spelling					
11. Did well only in writing and spelling					
12. Did poorly in all subjects					
13. Did poorly only in math					
14. Did poorly only in reading					
15. Did poorly only in writing					
16. Did poorly only in spelling					

C. 5

Patterns for secondary school target grades	Student Types 1	2	3	4	Total
1. Did well in all subjects					
2. Did well in only math					
3. Did well in only English					
4. Did well in only social studies					
5. Did well in only science					
6. Did well in only math and English					
7. Did well in only math and social studies					
8. Did well in only math and science					
9. Did well in only English and social studies					
10. Did well in only English and science					
11. Did well in only social studies and science					
12. Did poorly in all subjects					
13. Did poorly in only math					
14. Did poorly in only English					
15. Did poorly in only social studies					
16. Did poorly in only science					

C. 7 The Target Group's School Environment

Service Environment

Answer the next two questions Yes or No.

Is the quality of the service professionals as high as desired? ☐

Are non-classroom conditions as roomy and service materials in as great supply as desired? ☐

CHAPTER IV

USER INSTRUCTIONS FOR OPERATING THE MODEL

This chapter describes the steps that the operator of the simulation, referred to hereafter as the Program Administrator will take to operate the Cost Effectiveness model. He performs two important tasks: First, insuring that the information needed by the model to evaluate alternative proposals is complete and accurate; and, second, submitting runs to the computer and distributing computer output. Figure 1 illustrates these activities.

Data Collection and Preparation

Preparation for a model run will start when a project request is received from the field. The project request will be accompanied by information describing the project, the selected students, and their school environment. These data will be submitted on standard typed forms. The Program Administrator's job will be to ensure that the information is complete and accurate. A Preprocessor Computer Program will be provided to help accomplish this part of his task. The field data will be placed on punched cards and checked by the Preprocessor Program for completeness and consistency. Errors discovered by the computer will be printed and returned to the Administrator for correction. In some cases, such as those of errors of omission or keypunch errors in spelling or the like, the Administrator can make the corrections himself. For more serious errors, such as a case in which total cost might be less than the sum of its parts, he may have to seek counsel from the proposing district.

Several kinds of projects may be suggested in a single request. These can be either instructional projects or school service projects for one or more school districts. The Program Administrator will be responsible for sorting out the relevant descriptions of students and school systems. Suppose, for example, that the request calls for a free lunch program for the first three grades at P.S. 12 and 13, and remedial reading for grades four to six at P.S. 18 and 30 in a particular school district. The Administrator must be sure that separate information has been provided to describe the students in all six grades, as well as data about each of the four schools. This variety of information can be placed in the project data base, but the computer program will have to be instructed as to which child goes with which school (or classroom) for which project.

The Administrator is responsible for organizing the request into its separate parts, and instructing the computer program as to how he wishes the project analyzed. He is also responsbile for coordinating his project organization with the evaluation group in order that the computer model output will be meaningful.

Data Base Makeup

Once having obtained all of the field information necessary to analyze the project request, the Administrator will have to choose a set of model coefficients which are consistent with the type of student and the type of school district. The "closeness of fit" of his choices will depend upon his knowledge of how the model works. The coefficients are used in the cost-effectiveness model to project student achievement forward in time and different sets of coefficients will be provided for different school environments such as urban versus rural districts.

The Administrator will prepare his project organization on control cards. A separate control card will be provided for each separate part of the project request.

The three kinds of information - field data, coefficient selections and control cards - will be given to the computer. The computer program will search its master coefficient file for choices and create a community data base file. This file is called the project file, and all subsequent requests for cost-effectiveness runs for this community can be made directly from this file.

Model Runs

Running the model is the Program Administrator's easiest task. All that will be required will be the submission of his data base file with a request for machine time, since the file will contain all the control cards needed for model operation. The computer will make two passes for each separate part of the project request. The first pass, called the baseline run, will predict the consequences of the selected education system's operation without the presence of the Title I project. The baseline run is a prediction of the numbers and qualities of graduates, assuming that the school system remains the same as it is today. The second pass will be made with the Title I project included. The difference in results between the two runs indicates the specific impact made on the project. Data from each run will be collected and summarized in a separate schedule by the computer for the project as a whole.

We have described the activity schedule of the Program Administrator, taking him through the three major tasks of model operation: data collection and preparation; data base makeup; and, finally, Model runs. These will be his principal operating activities. It is possible, however, for him to provide certain other services to the evaluation group.

The model is designed to serve both as a production evaluation device, and as a research tool. This latter use requires, among other things, familiarity with the computer program, the data file, and the model coefficients. Separate parts of the model can be operated by a user upon the request of the evaluation group. In addition, the settings of the coefficients will be modifiable when, and if, research indicates that this should be done. The

Program Administrator will have to be trained by the model designers, Abt Associates Inc., as the computer program is developed. In addition, the Program Administrator Manual will contain detailed instructions for both operating the model and updating the coefficients.

PROGRAM ADMINISTRATION ACTIVITIES

	Source	Operation
Data Collection and Preparation	Field	Fill-out questionnaire
	Data processing facility	Convert data to punched cards
	Machine processing	Run pre-processor computer program
	Administrator error analysis	Determine corrections needed
Data Base Makeup	Administrator error correction	Prepare field data cards
	Run control preparation	Prepare control cards
	Machine processing	Run Data Base makeup program
	Data processing facility	Save data base tape
Operation		Run cost-effectiveness computer program
	Machine processing	Save output tape
	Administrator	Print the output tape

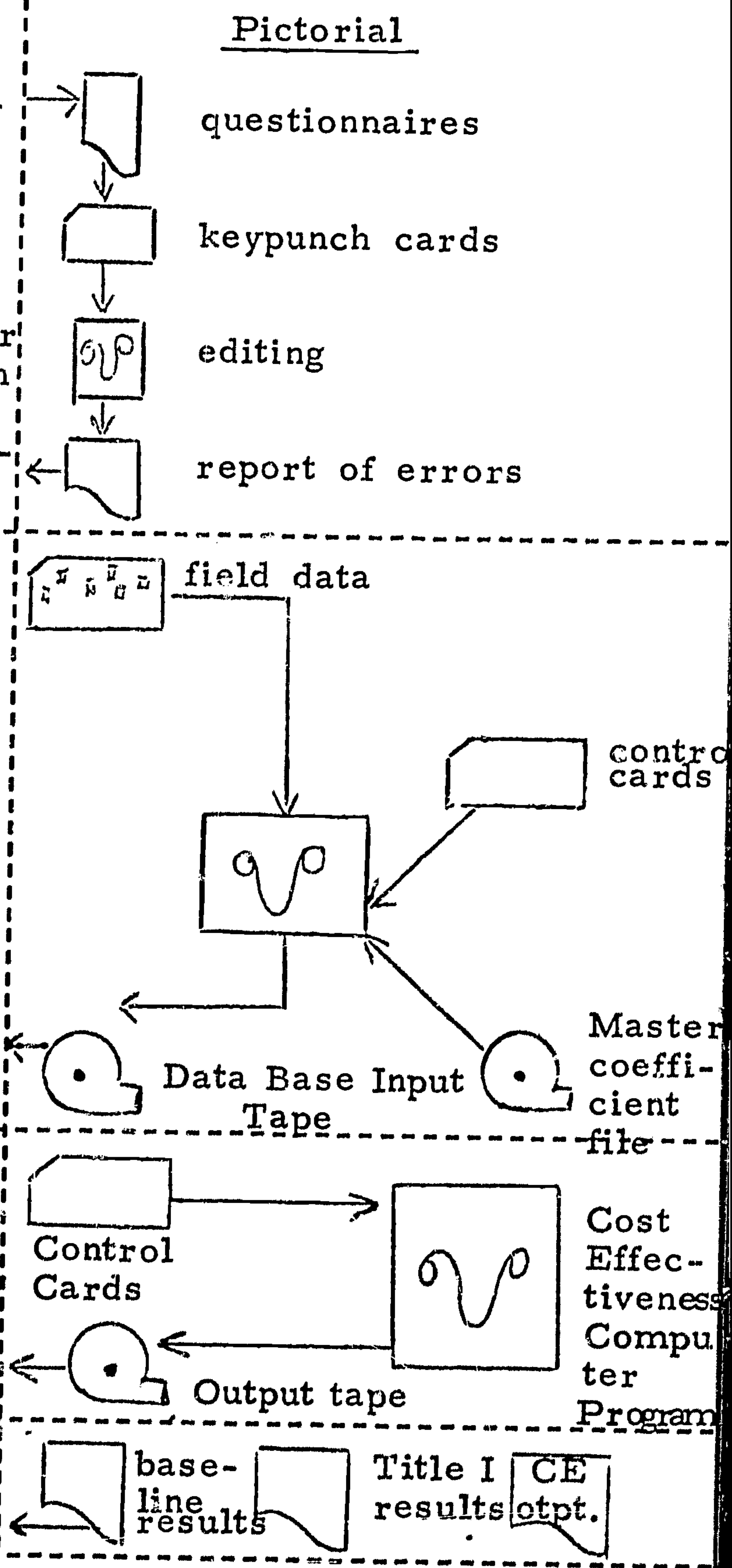


Figure 1

CHAPTER V

MODULAR OPERATION OF THE SUBMODELS

Although the OECE model is conceived as a whole entity for multi-faceted analysis of proposed Title I programs in terms of scholastic, community, and economic effects, it will be possible to operate its various component submodels individually or in any logical combination. For actual program evaluation, as a part of the Title I fund-allocation decision process, the entire model will be used, but there are several situations in which operation of less than the complete model can be valuable. This being the case, we have designed the model so that it will be fairly simple to run its various submodels in isolation. It is expected that modular operation will be available on a time-shared computer system with a remote console at the Office of Education.

For example, if one wished to see how projected lifetime earnings change with different 12th grade achievement patterns, this evaluation could be accomplished by entering as input each of the achievement patterns to be considered, operating upon them with only the Community Effects submodel, and comparing the computed projections.

The following paragraphs discuss the possible purposes which may be served by such modular operation. These purposes fall roughly into two categories: 1) "tuning" the submodels and 2) familiarizing users and potential users with the performance characteristics of the submodels.

"Tuning" the Submodels

Prior to any actual planning use of the model, it will be necessary to check the predictions made by each of the submodels and, if required, adjust individual parameters to give results which seem reasonable in response to a broad range of input data characteristics. Finding the correct values to assign to these parameters will be a process of enlightened trial and error. The model, which is no more than the sum of its submodels, has been designed primarily on the basis of qualitative data--quantitative theory is sparse and, although it was used whenever available, contributed relatively little to the final model design. Consequently, although the model is based on the interaction of many diverse factors selected after careful study of the education problem, the exact magnitudes of many of these interactions are imprecisely known. That is, the model, after it has been programmed for use on a digital computer, consists of a set of interconnected submodels, each of which consists in turn of a number of mathematical equations interrelating the input data according to the same patterns which seem, on the basis of our research, to operate in the real world. But it is not always possible to deduce from observations of the real world whether, of two dissimilar factors which clearly both affect the same variable quantity of interest, the first factor has twice the effect of the second factor or has only one and a half times the effect, etc. For example, in the Instructional Process submodel we know only that, among other factors, change in teacher experience and change in recency of curriculum materials both are associated with changes in student achievement level.

The user has access to the parameters in the submodel equations which relate the two input variables to change in achievement and can set these parameters to any values he desires. In order to arrive at the correct relative weightings for change in teacher experience and change in recency of curriculum materials with respect to change in achievement level, the user will first set the controlling parameters according to his best "informed guess,"--say that change in teacher experience is 2.5 times more powerful than change in recency of curriculum materials in terms of the associated change in achievement level, i.e., a 10% increase in teacher experience would have 2.5 times the influence of a 10% increase in recency of curriculum materials. The user will then operate the Instructional Process submodel using a set of input data with which he is familiar--it may be real-world data or he may have made it up just for the purpose of "tuning" the submodel. But in either case he should have a feeling for the results which reasonably would be expected according to the changes in teacher experience and curriculum materials recency specified in these data. If, comparing the submodel's calculations with his intuitive expectations, the user finds that the submodel outputs contradict or do not quite match the results he has forseen, he can readjust the parameter settings and run the submodel again until he is satisfied with the submodel's predictions. When the user finds no substantial [illegible] and the submodel's predictions, he should then [illegible] each time varying either the [illegible] the change in teacher [illegible] that the submodel's predictions [illegible] If they do not he [illegible] the [illegible] procedure until he [illegible]

[illegible]

[illegible]

[illegible]

could thus familiarize himself first--by reading the appropriate chapters in this report--with the theoretical aspects of each submodel: the input data it requires, the outputs it generates, etc. He could then explore each of the submodels by introducing various sets of data to the submodels and observing the changes in the output in response to changes which he made in the input. In this way, the user would develop a feeling for how sensitive the submodels are to changes in the various input variables. Thus, he would be better able to evaluate predictions made by the entire model--to judge the significance of various changes in model outputs.

Another possible value of using the submodels individually or in various subsets of combinations relates to the problem not of evaluating but of planning Title I educational assistance programs. Access to the various submodels might be made available to local project planners who could then experiment with possible ideas for Title I proposals. This could have two useful results: 1) local project planners could compare their intuitive conclusions with the projections made by the submodels and provide constructive criticisms if they felt that the model was improperly tuned for their individual community and 2) project planners could explore some alternative programs in detail. It is possible that by studying the detailed calculations made by the submodels, planners might be aided in finding possible programs to combat a particular area of weakness.

A third group of potential users of the submodels is that of individuals engaged in modeling of educational processes. By studying the behavior of these submodels they may be aided in designing improved models which will eventually be used in conjunction with the present model or for its improvement and for the improvement of educational theory in general. Although the present model has been designed for evaluation, it will hopefully have utility in educational research and theory.

CHAPTER VI

ORGANIZATION OF THE COMPUTER SIMULATION

Introduction

The simulation will be used by the Office of Education to evaluate programs in particular communities. It will not be used explicitly to allocate all Title I money in an optimal way; that is, the model will not tell us to spend $300,000 in district A, $20,000 in district B, and so on for all of Title I. Rather it will tell us that for community A, program 1 yields better results for less money than program 2. The simulation will be an evaluation and planning tool, not a research instrument.

The model will compare the effects and costs of proposed programs or combinations of programs against a set of basic effects and costs which are derived by projecting current school district operations with no changes. In computer terms, this means we will compare alternative program runs against a base line run.

Although research use is not the goal of our model development effort, it will be necessary for the user to have the opportunity to investigate in depth the predicted results of different programs as well as the working of the model itself. An option for in-depth investigation enables the user to develop his confidence in and facility with the model to whatever level of detail he desires. The user may have a substantive interest in a part of the model such that he wishes to observe changes in variables which are not summarized in the ordinary evaluation summary. He will be able to investigate these changes.

The simulation is designed to accomplish four basic tasks:

1) Preprocessing of the field questionnaires,

2) Preparation of a data base,

3) Operation of the model for baseline and prediction, and

4) Summary of cost-effectiveness for alternative programs.

The simulation simplifies the Program Administrator's problem by centralizing all control functions and automatically handling these different activities. See Figure 1.

We shall describe the features built into the simulation for routine evaluation and why they are needed. We shall follow that discussion by describing some of the special features that are provided for research investigations. Let us start by stating the basic purpose for the simulation, namely, to provide output for each Title I project descriptive of the impact that the project is likely to have.

A prerequisite for operations is the preparation of a community data base describing the school or district being simulated. This data base is stored on magnetic tape and serves as the focal point for information to the cost effectiveness model. In effect, the data base represents the information about the school, Title I, and the disadvantaged student. In general terms, a projection is first made by the model without the Title I program; that is, a projection is made of the expected future effects on the community and students with no Title I changes; and, then, a projection is made of the expected future effects on the community and students with the proposed Title I program added. The difference between these two projections represents the impact of the proposed Title I project. The Program Administrator compares these impacts and their associated costs and decides which program is better for the community.

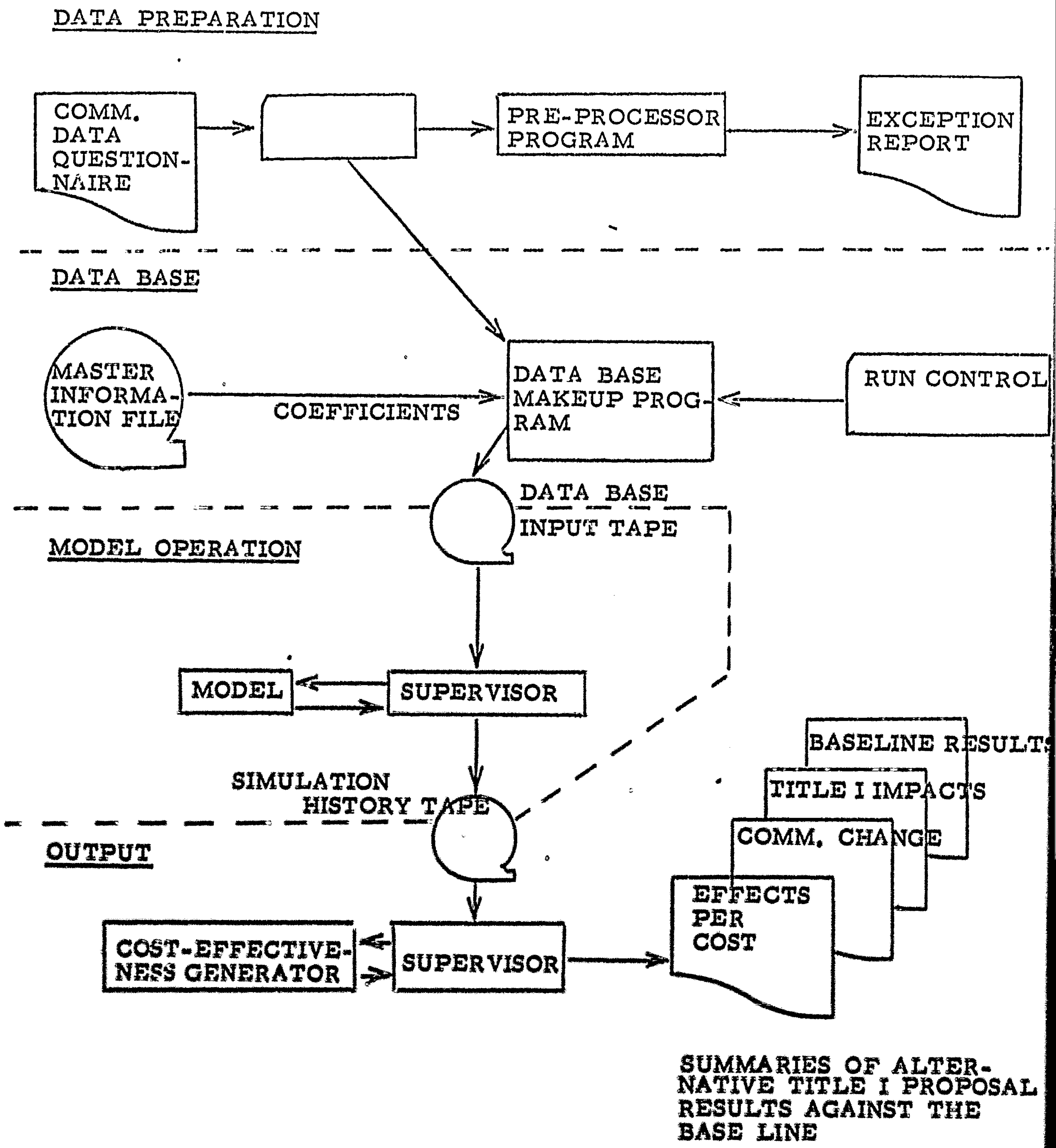
The Pre-Processor

Pre-processing is insurance. Pre-processing helps assure that the data used by the model will be self-consistent, that is, that mistakes will not be introduced by erroneous card punching or data omission.

The pre-processing computer program analyzes the data from the key punched field questionnaires and reports an error whenever selected built-in checks for consistency are violated. One such check concerns costs. If the sum of the component costs is not equal to the whole, an error has been made. Other checks are made using time, characteristics, achievement patterns and so forth. A report

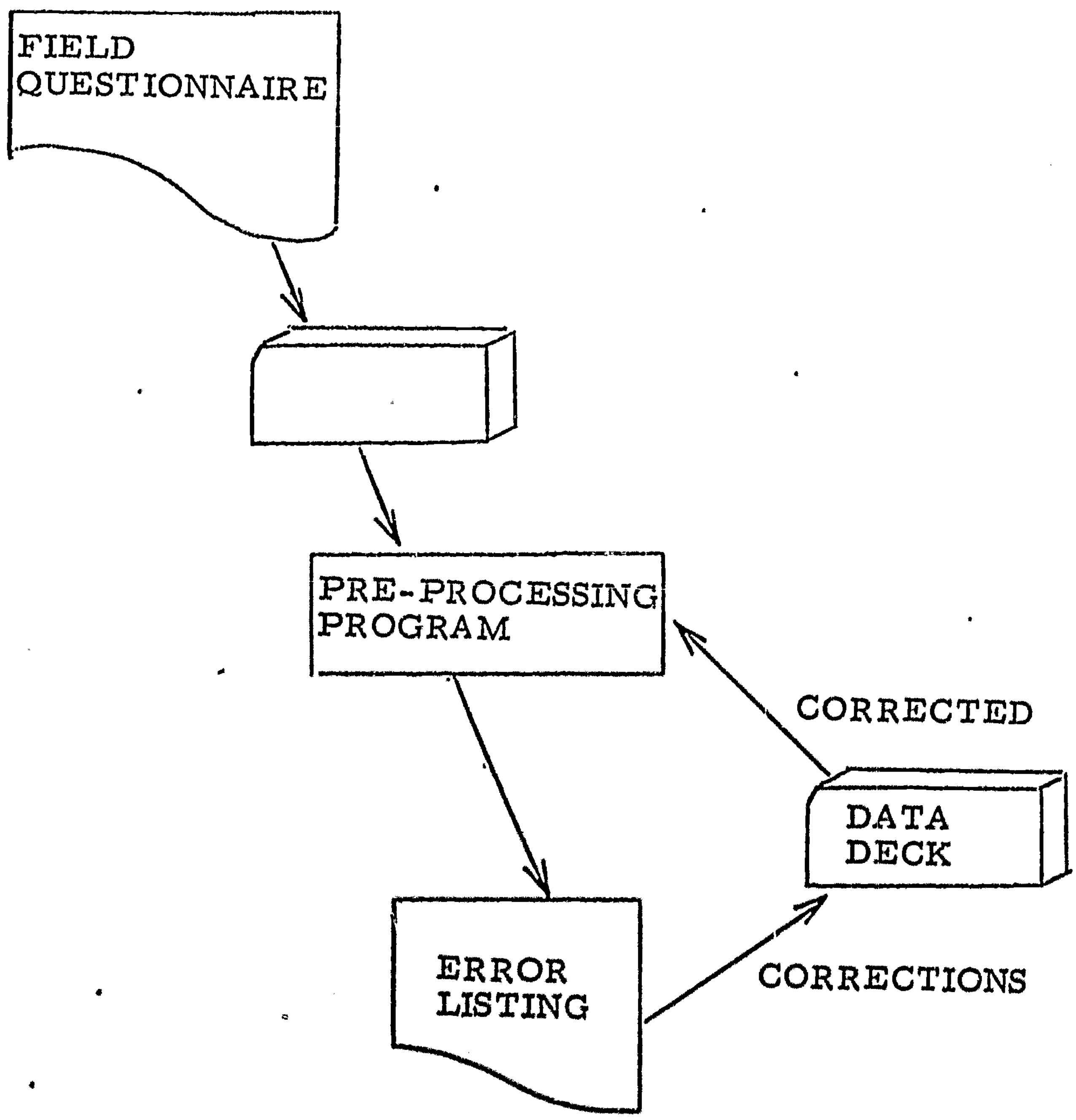
OECE COST-EFFECTIVENESS SIMULATION

Figure 1



PRE-PROCESSOR

Figure 2



This process is repeated until the Data Deck results in an error-free listing.

is generated by the pre-processor detailing its findings and the Program Administrator is asked to make corrections and provide the missing data. When the Administrator is satisfied that the input is correct, he can instruct the simulation to proceed.

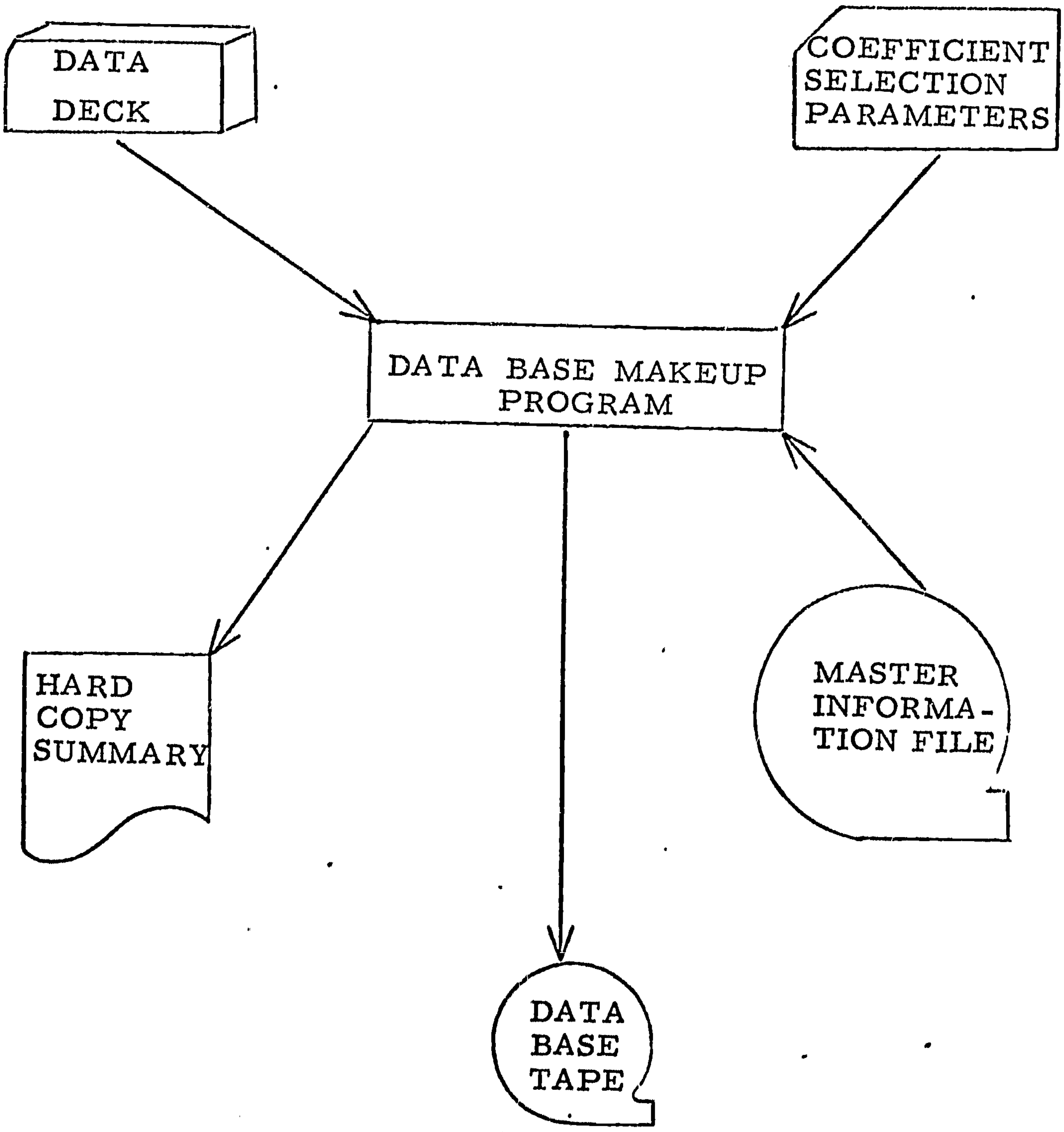
Data Base Makeup (Figure 3)

The data base is the repository of information from the questionnaires for use by the model. The simulation brings together consistent data from the Pre-processor about the school, the students, and the Title I project, a set of model coefficients chosen from the simulation master file of information, and control information necessary to operate the model. The data base is more than just a storehouse of information; it is an organized arrangement of data in a form ready for immediate use by the model. For example, some questionnaire information is keypunched as a yes or no answer. The model uses this answer as a variable setting. The question is transformed by the simulation in making up the data base into the particular variable setting required by the model. Let us consider an alternative way of doing this. Suppose that the Administrator were required to take the answers on the questionnaires and transform them into numbers representing the setting of variables. This would then require two things. First, he would have to know all the model variables, and second, he would have to know how to scale all the settings for each variable properly. This would be a great imposition when the simulation can perform this task so much more easily directly from the questionnaire information.

In order to save the Administrator the trouble of making variable settings, we provide a data base makeup program as a part of the simulation. Let us define a magnetic tape as a master file. Stored on this file are all the necessary elements for transforming the questionnaire information into the proper form. The master file also contains the coefficients needed by the model which remain

DATA BASE MAKEUP

Figure 3



invariant with different Title I proposals and communities. These coefficients embody the most recent research findings and expert opinions and, while subject to change, are in the short run, invariant.

The simulation makes up a data base for each community project by transforming the questionnaire data according to the rules provided, and then combining it with the constant information taken from the master file.

Model Supervisor (Figure 4a, 4b)

Perhaps the hardest function of the simulation to explain is model supervision. The supervisor acts like a big rotary switch, performing a sequence of control tasks one after the other. Let us look at what happens -- first, we have to hook up the data base without the Title I project, operate the model, and store the predictions on our history file. This baseline run provides the reference line for measuring the impacts of different Title I programs. Next, we have to repeat the process, except that this time we add the first selected sub-project from the data base. (The sub-project describes a particular target group within a particular project, e.g., third grade remedial reading). Again, we operate the model and store the predictions on our history file. We repeat this process as long as there are sub-projects to process, building up a sequence of results on the history tape. Finally, when there are no more sub-projects left for this community the supervisor turns its attention to retrieving the stored impacts, organizing them, and printing comparative results side by side. The supervisor keeps these activities separate, in proper sequence, and checks that the files are in working order.

Special Features

Having considered the operational functions of the simulation, let us examine some of the considerations that went into the simulation design. The simulation embodies flexibility, special file construction, ease of operation, and so forth, but the most important design concept in the simulation is modularity. What do we mean by modularity?

Think of a pre-fab house. Each piece comes complete, and the pieces can be put together in many interesting ways. The simulation is constructed just like the pre-fab house. But why go to all that trouble? The main thing we wanted was an operational facility and, at the same time, a facility that would allow experimentation with different parts of the model. Without modular construction we could not gain access to the pieces. Without a modular design of the data base we would not be able to operate different parts of the model with varying assumptions.

One way of providing modular construction and flexibility in operation is to separate the different simulation functions, such as preprocessing, data base makeup, or model operation by intermediate information files. This creates an added burden of file maintenance and updating, but provides and easy way to use the model for research.

One research objective might be independent operation of the Instructional Process Submodel. A specialized data base and parameter control are available to the user, when the simulation is run in this mode. The simulation has been designed to balance ease of operation for cost-effectiveness evaluations against alternative uses as a research tool.

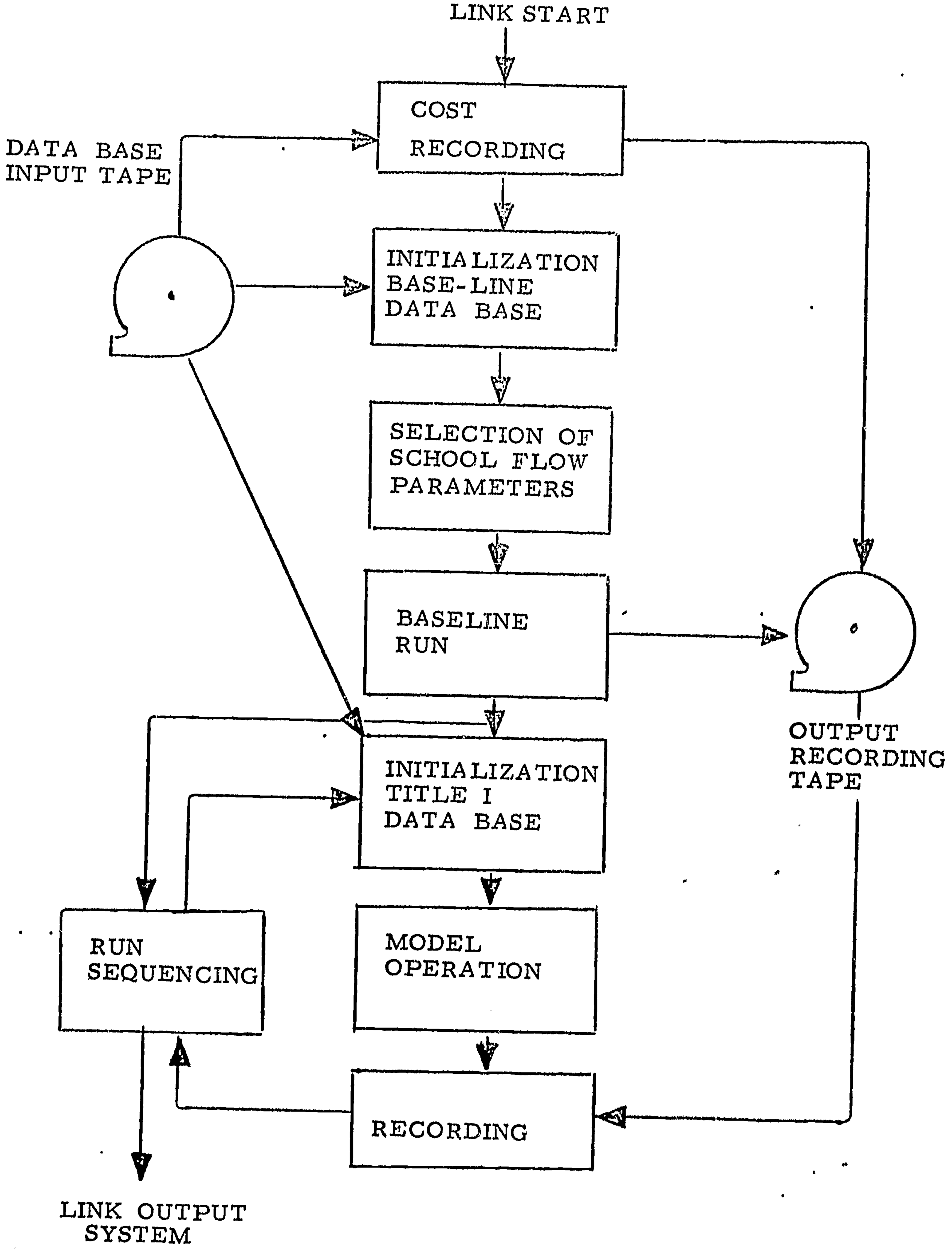
Special programs are provided to update the master information file. Each part of the model is built in the form of a replaceable module. This means that it is as easy for a programmer to replace an equation or a coefficient as it is for an electronic technician to replace a worn out tube or transistor.

Summary

In summary, the simulation controls the processing and error checking of the questionnaire data, as well as the operation of the Cost-Effectiveness model. It is constructed in a modular way that provides a high degree of flexibility in use and future growth, yet does not detract from its use as a facility for making routine evaluations of Title I fund applications.

MODEL SUPERVISOR

Figure 4a



OUTPUT SUPERVISOR

Figure 4b