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An elementary and secondary education cost-effectiveness model is designed, emphasizing evaluation of ESEA's Title I programs for the disadvantaged. Focusing heavily on student achievement, the model presents a means for evaluating by computer simulation the relative school, student, and community effects and associated costs of alternative Title I programs. The model contains four elements tracing the chronological effects of Title I programs on the students and based on the needs of the computer. The four elements of the model and their submodels are as follows: Input (cost), immediate Title I effects (instructional process), longer-range effects (school flows, dropout and truancy calculation, course of study selection, and community effects), and output (effectiveness outputs). (HW)

DESIGN FOR AN EDUCATION SYSTEM COST-EFFECTIVENESS MODEL

by

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This paper presents a design for an elementary and secondary education cost-effectiveness model, emphasizing evaluation of the U.S. Elementary and Secondary Education Act's Title I programs for the disadvantaged. Substantively, the design attempts to exploit available data on results accomplished by educational systems, as well as what is known about learning and influence processes. Methodologically, the design attempts a quantitative description of education systems, that may be programmed as a computer simulation that will produce quantitative indications of the relative impacts of alternative Title I projects on a given school, student group, and community.

The model at this writing has been partly programmed for computer simulation, and empirical data are sought for its validation.

The model was developed in 1966-67 under contract for the U.S. Office of Education's Division of Operations Analysis, by an interdisciplinary team at Abt Associates Inc., a private research firm located in Cambridge, Massachusetts. Some five man-years of professional effort were expended by fifteen professionals under the direction of the writer. The writer gratefully acknowledges the inspiration and encouragement given by Dr. Alexander Mood, Assistant Commissioner for Educational Statistics; the wise direction and warm support of Dr. David Stoller, Director of the Division of Operations Analysis; and Murray Spitzer, Chief of the Systems Analysis Branch; all of the U.S. Office of Education. Significant parts of the model design are the work of my colleagues at Abt Associates Inc., Stephen Bornstein, Louis Cutrona, Stephen Fitzsimmons (deputy project director for data analysis), Grover Gregory, James Hodder, Peter Miller (initially deputy project director for computer simulation design and project director as of January 1967) Martha Rosen, Richard Rosen, and Herbert S. Winokur. Professor André Danière and Mr. George Thomas of Harvard University generously gave advice and information.

THE OVERALL MODEL AND THE SUBMODELS

The purpose of the overall education cost-effectiveness model is to evaluate the relative school, student, and community effects and associated costs of alternative U. S. Elementary and Secondary Education Act of 1965 Title I programs for the disadvantaged.

Since such programs are directed toward increasing learning, the model focuses strongly on the changes in student achievement, the attitudes and environmental factors influencing achievement, and the social behaviors and community impacts of improved achievement in the target population.

The model may be described as a partly micro-educational model, because of its representation of some of the detailed components of the education process. However, the model does not pretend to be a micro-analysis of learning and influence processes, although these processes are represented by whatever objective correlatives are available in the form of qualitative numerical indices. Refinement of the model design is continuing. This description is current for November 1967.

The model also does not pretend to be an exhaustive representation of what leads to changed student achievement, attitudes, earning potential, and equality of educational opportunity. The attempt was to emphasize those aspects of the education process that seem most relevant to achievement increases in students affected by Title I programs, and for which quantitative data is widely available.

Some attitudinal variables believed decisive for the learning process are not yet quantitatively defined, and there is only qualitative, impressionistic data available on them. Rather than simply omit such troublesome but significant variables, and thus falsely imply insignificance by omission, the qualitative variables are sometimes given numerical index ratings roughly corresponding to such qualitative distinctions as are offered by empirical but impressionistic data. In other cases, qualitative variables are built up numerically from components for which better data is available, or assigned index values by user judgment. In all cases, the attempt has been made to achieve a useful balance among the demands for compact data input, limited model complexity, and validity of output.

The model's emphasis is on what the education system produces in terms of quantities and qualities, rather than how it does so. However, a certain amount of detail on how it produces its effects was essential to simulate for forecasting what it will do.

The model is not initially expected to be predictive, but only indicative of the relative cost-effectiveness of alternative Title I programs. Prediction requires regularity of process, and no two schools, student populations, or communities are alike. Even the calibration of the model with previous Title I before- and-after data will only improve its indication of the probable relative effectiveness of programs, because of the uniqueness of each case. Only to the extent that Title I situations are similar and are accurately measured and modeled, can their impact be forecast. However, even such a limited cost-effectiveness forecasting and evaluation model as that described here offers a substantial aid to education planners and policy-makers.

The 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

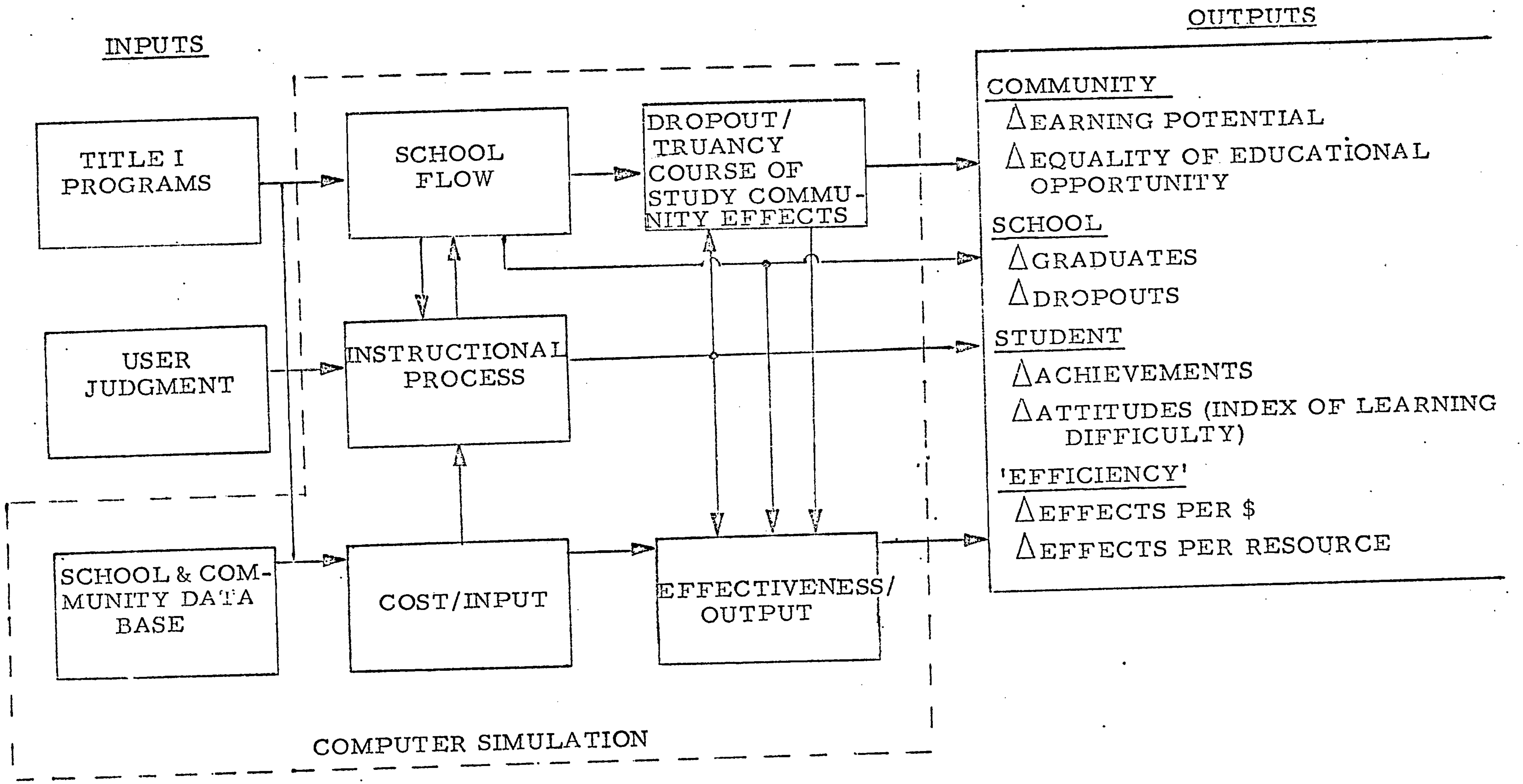


Figure 1: Cost-Effectiveness Model Overview Showing Inputs, 7 Submodels, and Outputs.

The Cost/Input Submodel accounts for costs required to implement Title I programs. It allows the user to associate specific costs with specific components of the program and their effects. Inputs are the Title I program description and costs, and the real national average costs of typical Title I items. The submodel compares typical and proposed expenditures. Outputs are the total costs of the program, the added resources bought, and total program costs broken down by component parts.

The Instructional Process Submodel represents the improvements in specific student achievement and attitude resulting from a Title I program. It attempts to reproduce the effects of the influence process whereby behavior and attitude are modified by exposures to teacher, parent, and peer of varying duration and intensity. Inputs are the Title I program, previous and current changes in attitudes and achievements, and sociological data. Outputs are changes in achievement and attitude ("Index of Learning Difficulty") by student type in the Title I target population.

The School Flow Submodel represents the production process whereby the inputs of four partially educated student types (white and non-white, above and below $2,000 family income) and education resources (teachers, equipment, facilities, community environment) are transformed into better educated individuals. Based on both past grade-to-grade changes in student achievement patterns and changed achievement as a result of Title I programs, the submodel indicates "downstream" achievement through dropout or graduation.

The Dropout/Truancy Calculation Submodel determines the dropout and truancy rates for the years during and after the Title I program. It takes as input pre- and post-Title I achievement and pre-Title I dropout and truancy rates.

The Course of Study Selection Submodel represents the choosing of a course of study by students at some point in their school career. Inputs are pre- and post-Title I achievement and course of study selection by student type.

The Community Interactions Submodel estimates the impact on two community variables of the changes in education system output due to Title I programs. The inputs are the School Submodel outputs of changes in numbers of graduates, dropouts, and achievement levels; the Instructional Process outputs of changed student achievement and attitude; and community characteristics from the Data Base. Outputs are the community changes in terms of changes in lifetime earning potential and equality of educational opportunity of the Title I target population.

The Effectiveness/Output Submodel is the submodel in which the analysis and the output of the results determined by the other submodels takes place. The inputs to the Effectiveness Submodel are all of the variables which are in the Data Base at any time, the outputs of all of the above submodels (i.e., student, school, and community effects), and their associated costs. Outputs are efficiency data, measures of education effectiveness, and descriptive school, student and community data. Specific efficiency measures are effects per cost, and effects per resource.

The outputs of each Title I program would be evaluated by a model "run," and comparison of alternate programs can be made by comparing respective effects and costs. Both different programs for the same target population, and with some reduced realism, the same or different programs for different target populations may thus be compared in a given community. The tables below are (fictional) examples of typical computer printouts (output) of a model run for a single specific school improvement project, giving before-project and after-project achievement, attitude and economic data on students by population type.

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
PROJECT	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
PROJECT	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	.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	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
PROJECT	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
PROJECT	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
PROJECT	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
PROJECT	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; 2-NONWHITES, MORE THAN 2000; 3-WHITES, LESS THAN 2000; 4-WHITES, MORE THAN 2000

FIGURE 2

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

The following sections describe the seven submodels in more detail.

THE COST /INPUT SUBMODEL*

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 phychiatrist 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.

A flow chart of the submodel's functions is shown in Figure 2 on the next page.

* Designed principally by G. C. Gregory and M. O. Rosen.

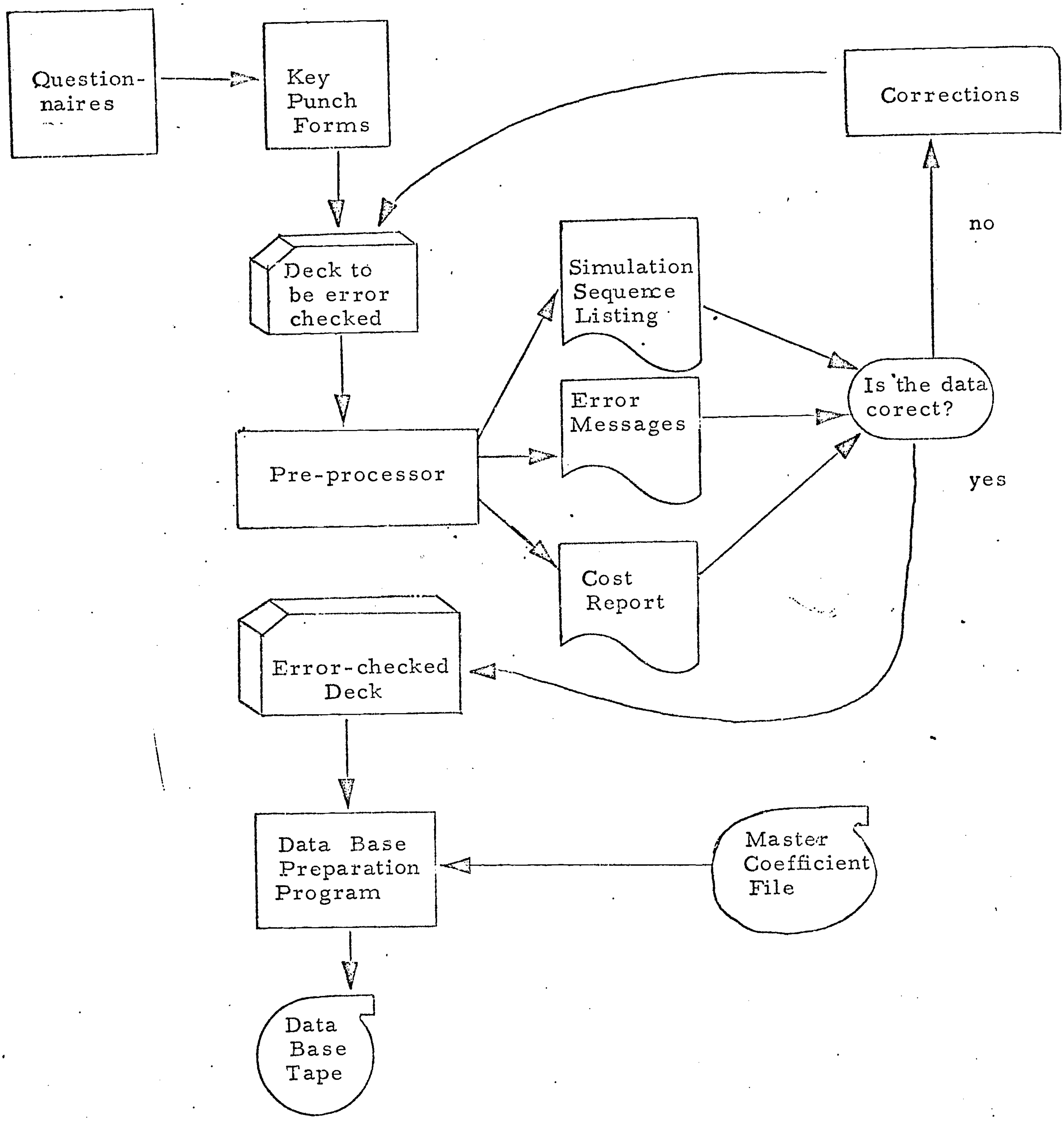

Question-
naires
Key
Punch
Forms
Corrections
no
Deck to
be error
checked
Simulation
Sequence
Listing
Is the data
corect?
Error
Messages
Pre-processor
yes
Cost
Report
Error-checked
Deck
Data Base
Preparation
Program
Master
Coefficient
File
Data
Base
Tape

Figure 4

THE INSTRUCTIONAL PROCESS SUBMODEL*

The immediate achievement changes in the target student population resulting from Title I educational programs must be predicted and provided to the School Flow Submodel, so that these changes may be propagated "downstream" in time to forecast expected changes in the number of dropouts and the number and achievement levels of graduates. The immediate target population achievement changes due to Title I are computed in the Instructional Process Submodel. (See Figure 5 below.)

The Instructional Process Submodel computes estimated expected academic achievement and attitude changes from the changes in the scholastic environment as decomposed into its instructional and service (sociophysical environmental) components.

The instructional component subroutine of the overall school environment is expressed in terms of the changes in the quality and the quantity (intensity and duration) of classroom instruction. The quality of instruction is given index values on the basis of such objective and measurable factors as teacher education and experience, and degree of recency of curriculum materials. In addition there are interaction factors affecting the index of instructional quality, such as the increased criticality of teacher quality when curriculum quality and recency is poor. The significance of these interaction factors is weighted by model user judgment, or in a way corresponding to the amount of the variance accounted for by them in the 1966 U.S. Survey of Equality of Educational Opportunity.

The quantity of instruction consists of its intensity and duration, giving a measure of overall exposure. Intensity is measured by teacher-student ratio and equipment (books, desks, aids, etc.) per student.

The service component subroutine deals with those aspects of programs intended to reduce the environmental impedances to scholastic achievement, such as school lunch programs. Some of the environmental impedances considered include low family income, physical handicaps, uneducated parents, disrupted family life, low individual achievement, and low peer group achievement levels. These are aggregated into an

* Designed principally by S. A. Bornstein and J. C. Hodder.

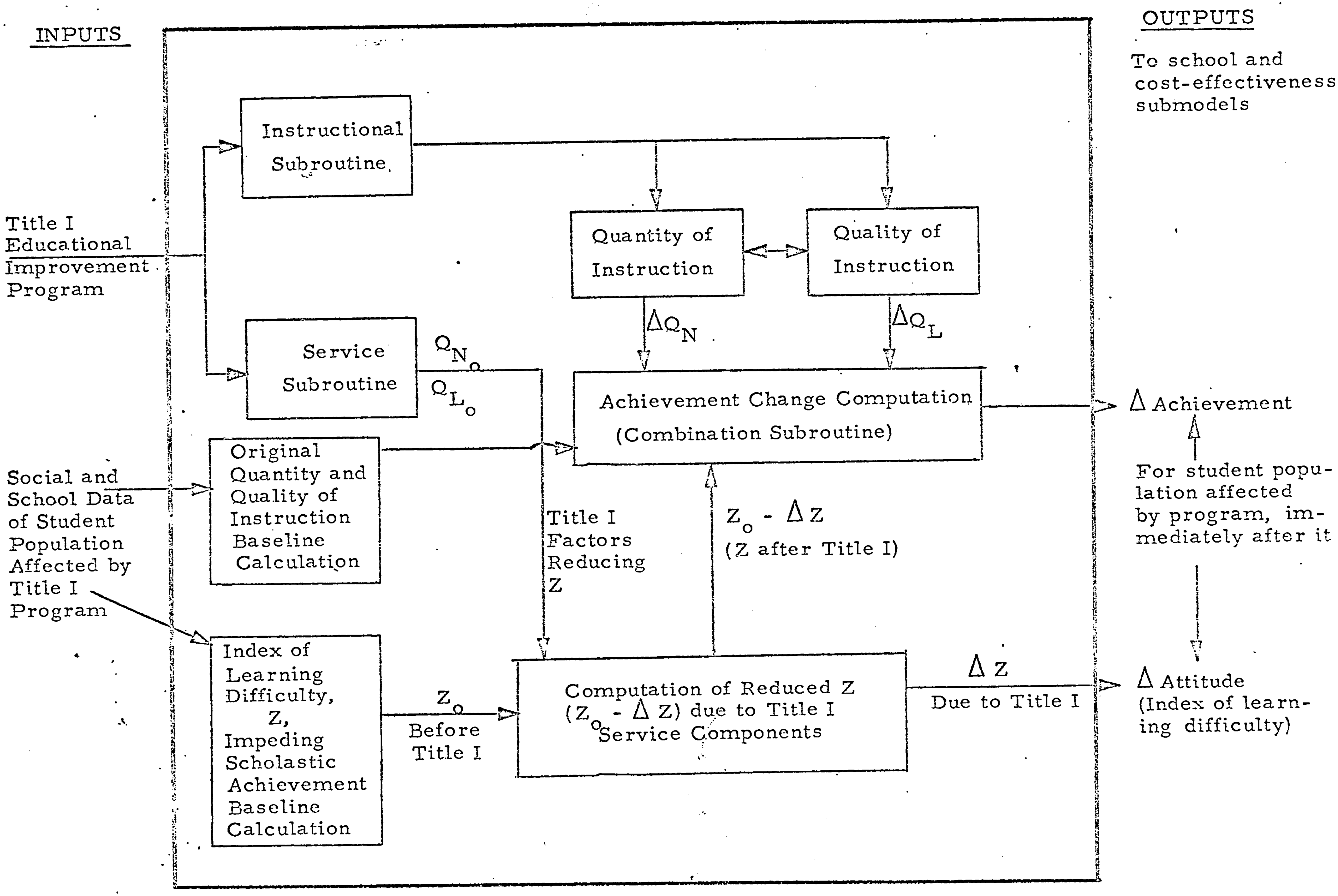


Figure 5 Instructional Process Submodel

overall index of learning difficulty, or target-population-specific impedance, Z. The reduction in Z is calculated on the basis of the individual Title I program's service components' reduction of the environmental impedances. A baseline calculation subroutine accumulates the target student population's achievement and impedance characteristics before the Title I program.

Student achievement change due to the Title I educational improvement program is then computed in a combination subroutine, on the basis of quantity of instruction multiplied by quality of instruction, all divided by the new (reduced) index of learning difficulty. This achievement change only refers to the period of time over which the educational improvement program operates, and the subject areas covered by it. This "local" achievement changes must be propagated to later grades and other subjects in the school submodel, before the impact on dropouts and graduates can be estimated.

THE SCHOOL FLOW SUBMODEL*

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 preceding 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.

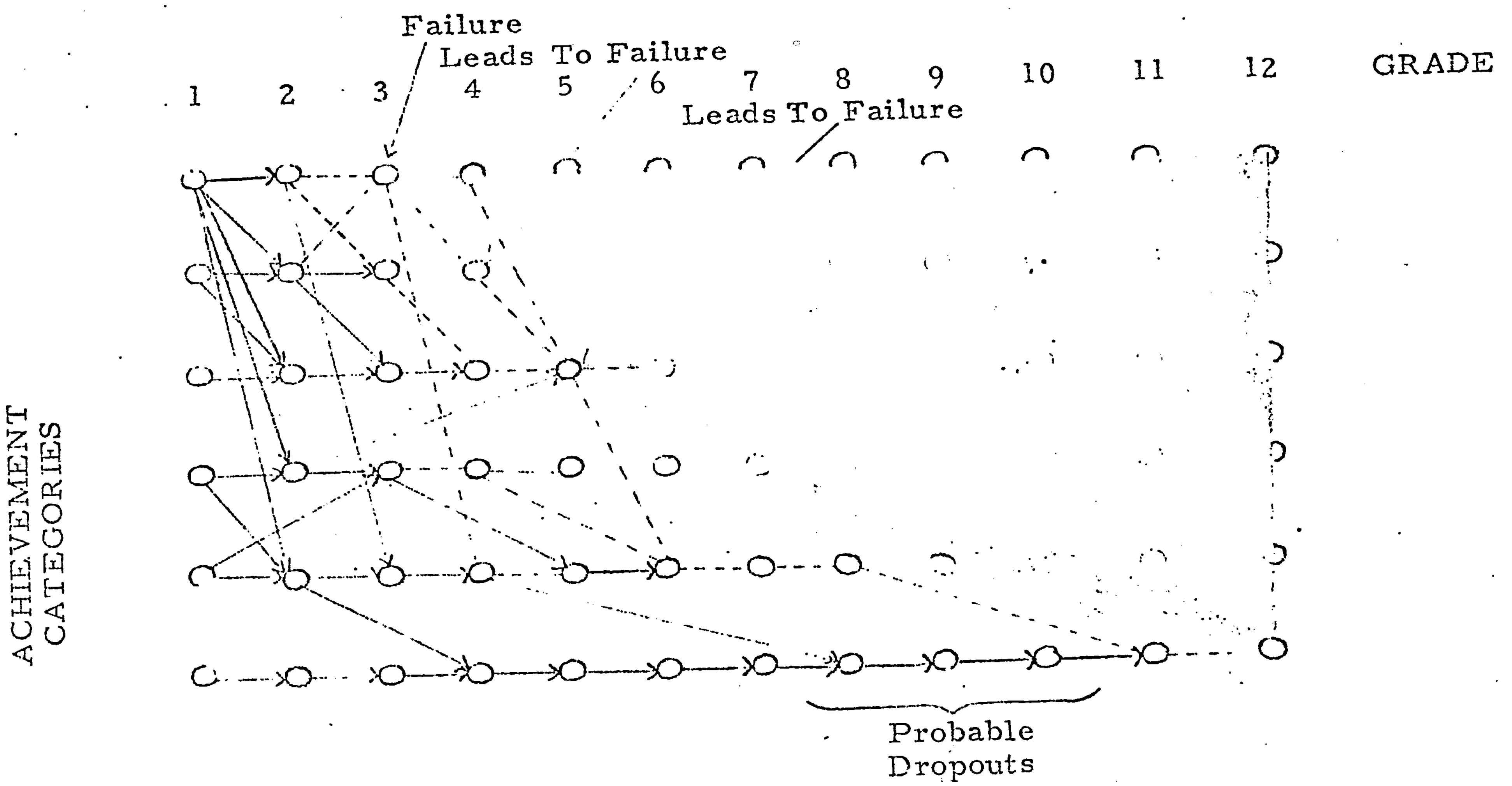
The model uses conditional probabilities to predict the achievement pattern in a given grade from the achievement pattern in the previous grade. The probabilities are of the form: "Given that a student in the fourth grade passed English, social studies, and science, and failed mathematics, the probability 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-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 Figure 6.

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

* Designed principally by H. S. Winokur and C. C. Abt.

Figure 6

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



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 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 later, 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.

THE DROPOUT/TRUANCY SUBMODEL*

This submodel attempts to 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, can be transformed into projected changes in achievement after the Title I program has been applied. These changes are then projected by the School Flow Submodel. 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 below.

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.

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* Designed principally by H. S. Winokur and P. S. Miller.

There are many factors which affect the dropout and truancy rates; these factors can generally be categorized as community factors, impedance factors (see the Instructional Process Submodel) 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.

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.

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 impedance 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 possibly 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.

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. 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 School Flow Submodel--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

* Designed principally by P. S. Miller and H. S. Winokur.

against the constraints determined by the school and adjustments are made until the proportions satisfy these constraints.

In the School Flow Submodel, the expected achievement and standard deviation of achievement for the average student are 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 7.

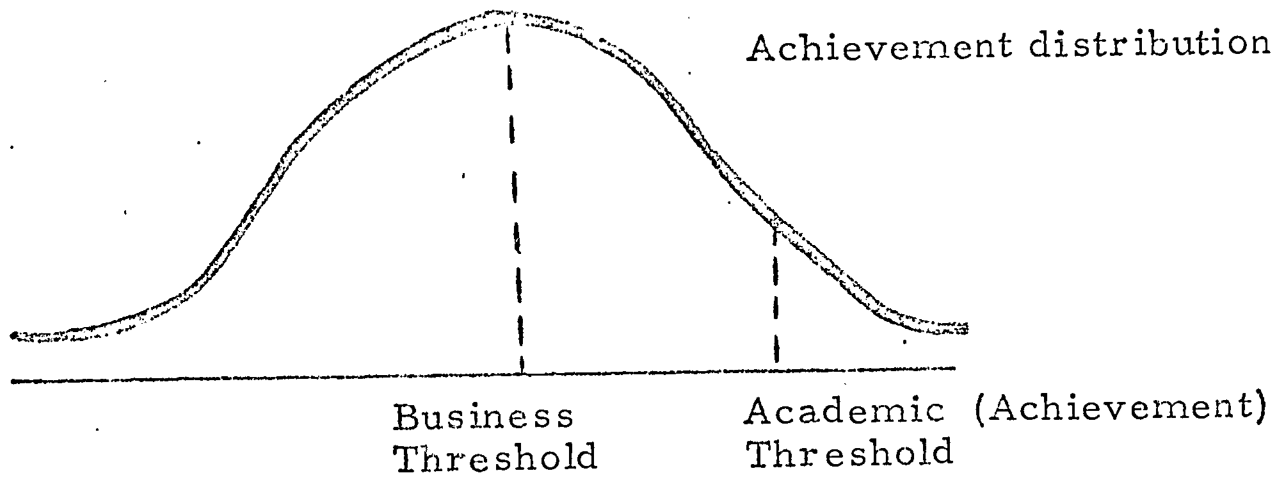


Figure 7

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.

THE COMMUNITY SUBMODEL *

The Community Submodel as it now stands consists of two independently operating subroutines which convert Data Base information, Instructional Process Submodel attitudinal and School Submodel achievement data into indicators of lifetime earning potential and equality of educational opportunity. These outputs were selected on the basis of presumed interest to Title I evaluators. Present and past values for these outputs for a particular community can be readily determined; the Title I evaluator's concern is the predicted future values which incorporate both Title I inputs, tracing their community effects, and extrapolated community trends contributing to a change in these indicators relatively independent of Title I.

For long-range planning it would also be desirable to cycle these outputs back through the community to see how they affect the School and the Instructional Process. A complete full-scale working model of the community would perform such desired functions. However, data gaps and the absence of systematic research findings on the majority of the many components of a complete Community Model leave too much to speculation. ** The current Community Submodel represents the alternative of higher reliability on a much more limited scale. The two criteria for selection were relative reliability; i.e., areas in which extant research has at least pointed the direction of relationships, and interest for immediate Title I evaluation needs. (See Figure 8 below.)

The main implication of the first Base Line Run for the Community Subroutine logics is the establishment of threshold values; this is the "tuning" of the submodel. Once these threshold values are established, the Model is run with the projected Title I program inputs. Resultant changes in Instructional Process achievements and attitudes are passed on to the Community subroutines where

* Designed principally by S. J. Fitzsimmons, and P. S. Miller.

** This finding is based on a full-scale theoretical modeling effort carried out earlier in the history of this project. The results of this feasibility study are nevertheless generally favorable, given the possibility of a larger scale effort with an associated research program.

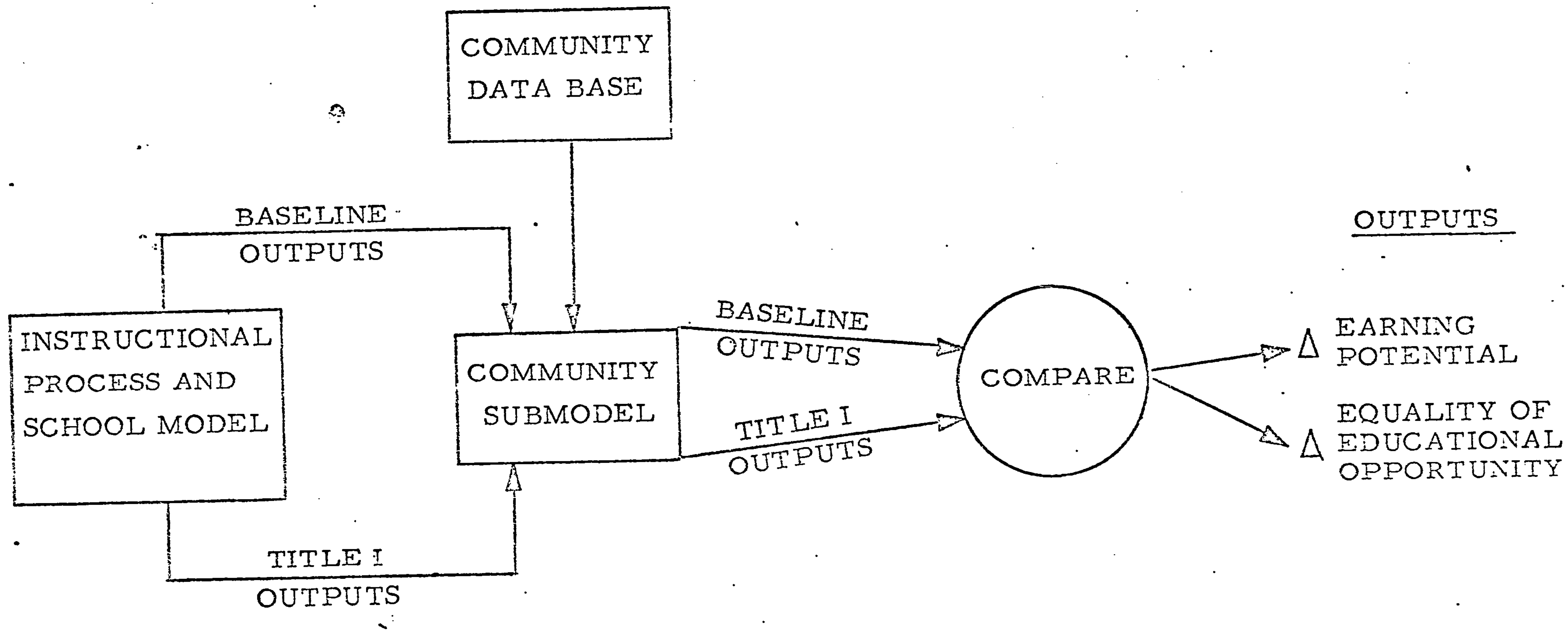
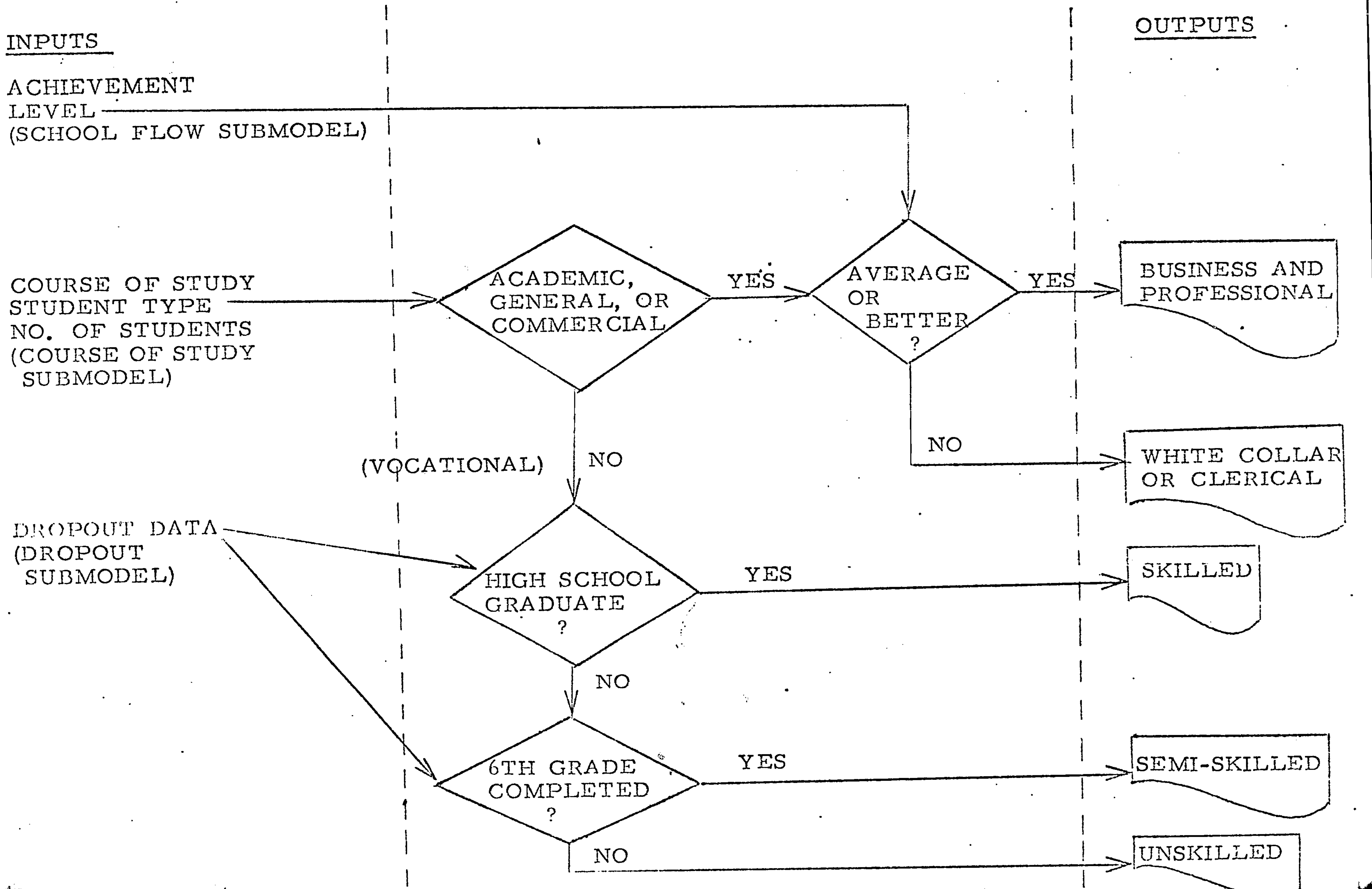


Figure 8 Community Submodel

POTENTIAL LIFETIME EARNINGS SUBROUTINE

Figure 9



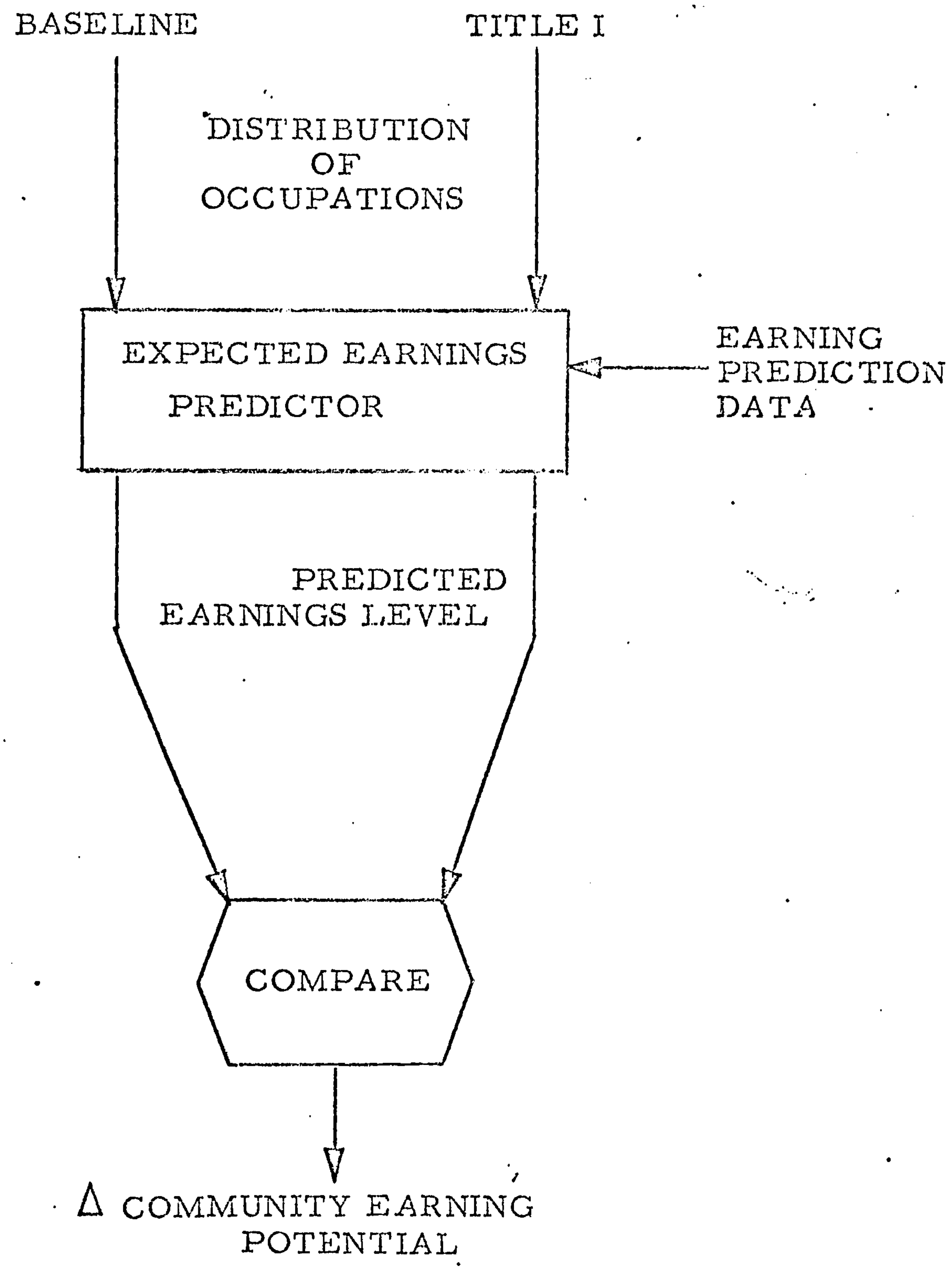


Figure 10 Translation of Occupation to Income

Equality of Educational Opportunity

A major aim of Title I is to equalize educational opportunities throughout the U.S.A. Since "opportunities" themselves are difficult to measure directly, this subroutine design utilizes Coleman's logic in deriving an indicator of the quality of educational opportunity. Coleman argues that inequalities of educational opportunity exist where scholastic achievement scores are correlated with socio-economic level. Where equality of educational opportunity is high, there would be no correlation with social origin (measured by income and race in this model). 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.

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 earlier, 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.

THE EFFECTIVENESS OUTPUTS SUBMODEL*

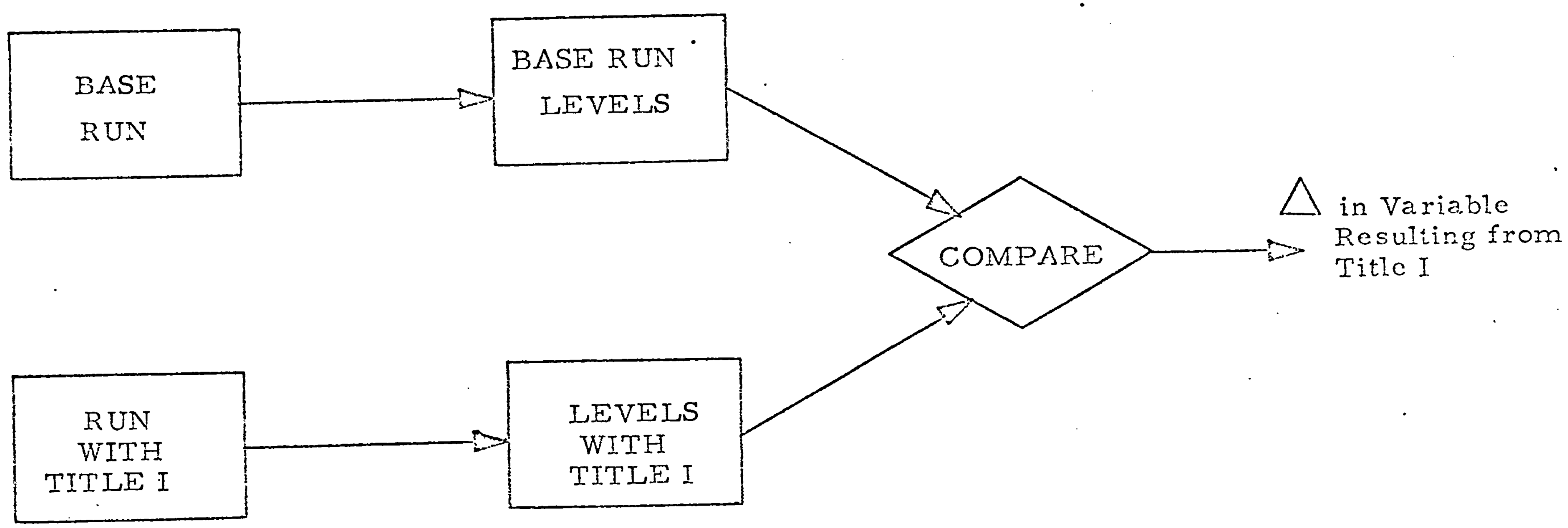
The overall model will simulate particular school districts and their output in terms of student changes and community impacts. This simulation is done, in particular, by the School submodel, the Instructional Process submodel and the Community submodel. The Cost submodel determines the costs of the various Title I inputs and the on-going school expenses. The Cost-effectiveness submodel receives the outputs of these four submodels and the updated data base, and provides an output for the user indicating relative educational cost-effectiveness, or efficiency.

Figure 11 shows two kinds of outputs which are generated by the simulation. If we operate the model without any Title I programs (the base run), the output will be in terms of pre-Title I levels of student achievement levels and community impacts. These pre-Title I levels are important for testing the model and tuning the judgment parameters in it.

After making the base run, the simulation is operated with a proposed Title I program. The output of this run will be another set of levels of student change and community impact, but these are not very useful by themselves. The only way to determine the impact of a Title I program is to compare the base run with the Title I run. Thus, the second kind of output derived from the simulation is a set of changes (or deltas) for each of the variables of interest.

Figure 12 shows the changes (Δ) resulting from Title I programs derived from the simulation, and the outputs which are drawn from them. We are interested in the effects which occur as a result of the introduction of the Title I input, and what they cost. However, this sort of output may not be very useful for comparison of alternative Title I programs, since different resources are likely to be used by different programs. It is therefore necessary to convert resources into some common unit, the most obvious being dollars. The effect per dollar change may then be computed. For the same reason it is necessary to convert effects into common units, so that alternative programs with different effects and resources can be compared along some common dimension.

* Designed principally by P. S. Miller.



EXAMPLES:

FOURTH GRADE

READING LEVEL = SECOND GRADE

FOURTH GRADE △

△ READING LEVEL = + ONE GRADE

Figure 11 Simulation Results

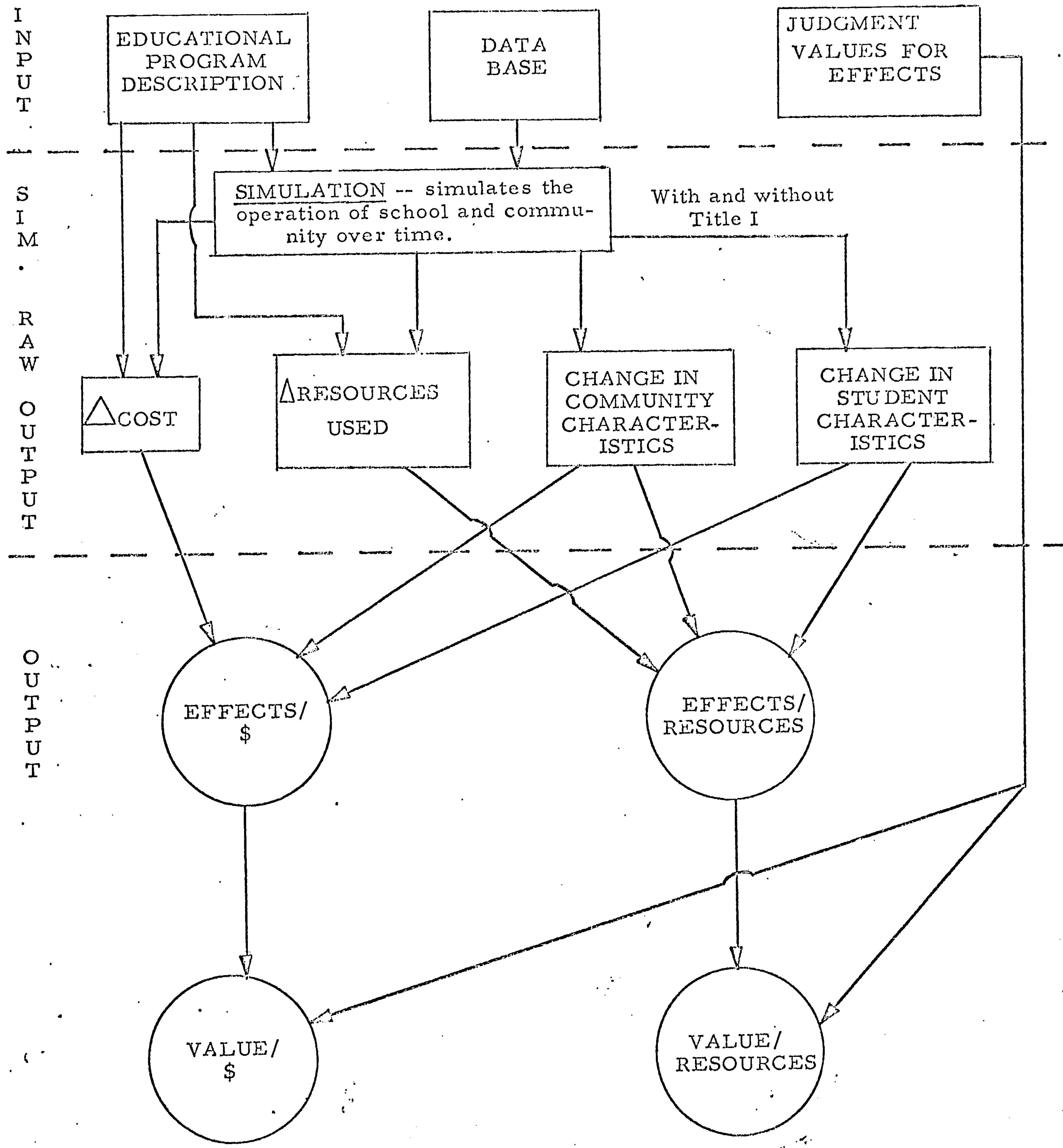


Figure 12 Outputs from the Simulation

The unit for the comparison of effects is value. The value for a given degree of change in each of the various effects is a judgment input, obtained from the user. Given changes in effects weighted by their associated values, and the resource changes described in terms of dollars, the value per dollar of a given Title I program can be estimated.

In the case where only one scarce resource (e. g., textbooks, teachers, schoolrooms, etc.) is being introduced by a Title I program, the amount of a value resulting from an increased amount of that resource may also be a useful output.

Figure 13 shows the simulation and its operation.

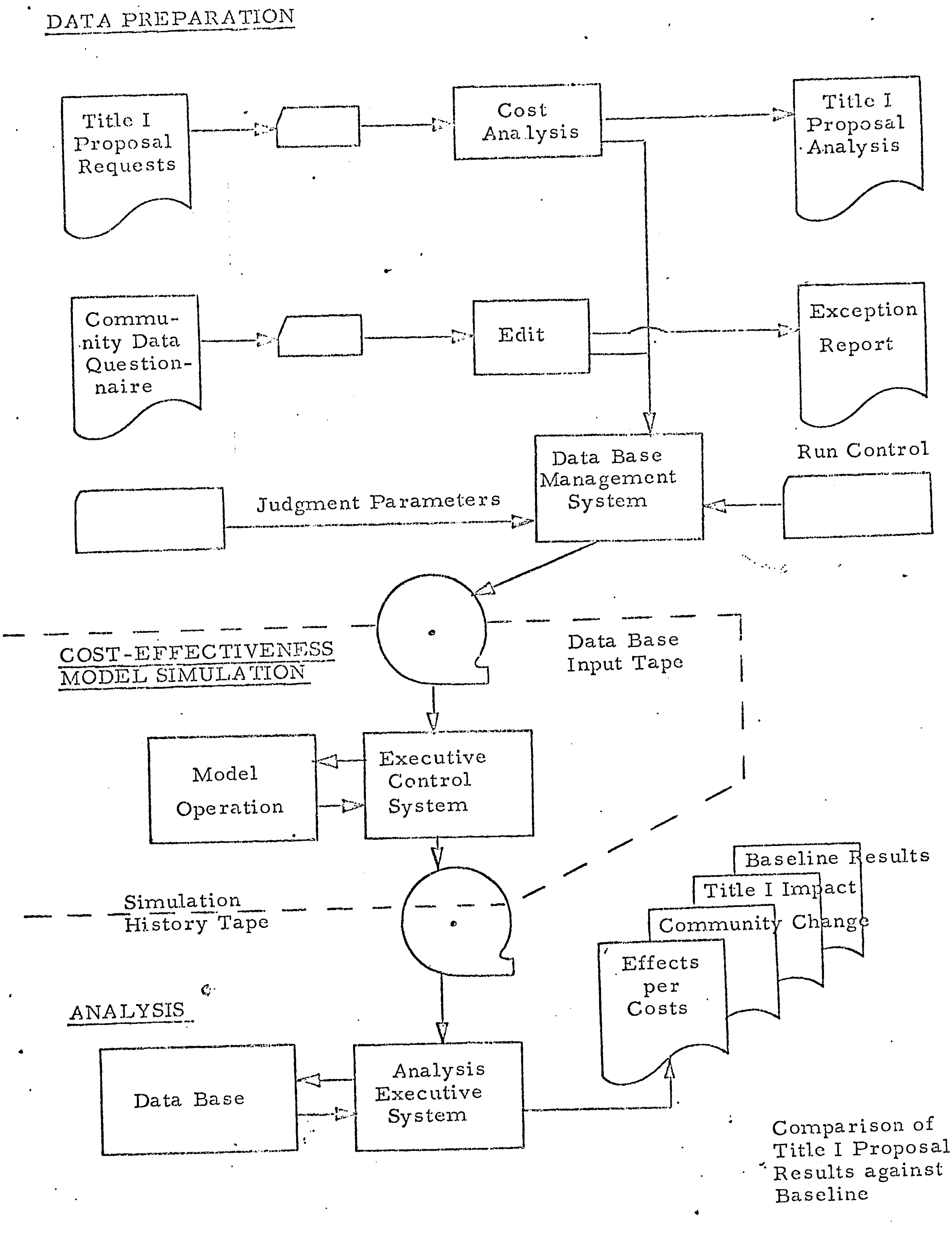


Figure 13 Education Cost-Effectiveness Computer Simulation