R E P O R T   R E S U M E S

ED 010 579   56

A COMPUTER SIMULATION VEHICLE FOR EDUCATIONAL SYSTEMS.

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REPORT NUMBER NDEA-VIIA-1130-22   PUB DATE 22 MAR 65

REPORT NUMBER BR-5-0738-22

REPORT NUMBER TM-1493-314-00

GRANT OEG-7-14-9120-217

EDRS PRICE MF-$0.09 HC-$1.32 33P.

DESCRIPTORS- *SIMULATION, *MODELS, *SYSTEMS ANALYSIS, *COMPUTER PROGRAMS, EDUCATIONAL PLANNING, SCHOOL ORGANIZATION, *STUDENT CHARACTERISTICS, HIGH SCHOOLS, SCHOOL DESIGN, SANTA MONICA, CALIFORNIA

CHARACTERISTICS AND CONSTRUCTION OF A COMPUTER SIMULATION MODEL FOR SIMULATING BEHAVIOR OF STUDENTS AND STAFF IN A SCHOOL WERE DESCRIBED. THIS MODEL INCORPORATED SYSTEMS ANALYSIS AND COMPUTER SIMULATION TECHNIQUES AND WAS EXPECTED TO PROVIDE DESIGN RECOMMENDATIONS FOR MORE PERVASIVE AND INTERGRATED CHANGES THROUGHOUT THE SCHOOLS. THE MODEL WAS CONSTRUCTED SO THAT A HIGH SCHOOL CAN BE DESCRIBED IN TERMS OF SCHOOL CHARACTERISTICS AND STUDENT CHARACTERISTICS THAT BEAR ON THE INSTRUCTIONAL PLAN OF THE SCHOOL. A FULL DESCRIPTION OF THE MODEL AND PLANS FOR SIMULATION OF SELECTED HIGH SCHOOLS WAS PRESENTED. RELATED REPORTS ARE ED 010 559 AND ED 010 577 THROUGH ED 010 581. (RS)

VII A-1130
(S-0730)

The research reported herein was conducted under SDC's independent research program and supported in part by Grant 7-14-9120-217 from the Office of Education, U. S. Department of Health, Education, and Welfare.

TM-1493/314/00

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RELEASE
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DATE 3/22/65 PAGE 1 OF 31 PAGES

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a working paper

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A Computer Simulation Vehicle for Educational Systems

ABSTRACT

This document describes the characteristics and construction of a computer simulation vehicle for simulating behavior of students and staff in a school. The School Simulation Vehicle is a major phase of a project making use of techniques relatively new to educational research--systems analysis and computer simulation. The purpose of the research is to find new solutions to implementing instructional media through analysis and simulation of school organization. The text of this paper has been prepared from detailed memoranda produced throughout the project's development. Source memoranda referenced in section titles of this paper are described in the bibliography on page 31. These memoranda are available in limited quantity from the Education and Training Staff, System Development Corporation, Santa Monica, California.

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1. Introduction (1)

Although great strides have been made in the development of educational methodology and technology during the past twenty years, the formal organization or structure of education has remained relatively constant despite obvious weakness in its ability to adjust to instructional innovations.

A major reason for this lack of change is the complexity of designing school organizations that efficiently accommodate modern instructional media. An innovation such as programmed learning, for example, if used on a large scale in a school, has implications for the organization of the whole school. By providing a means of effective self-study, it may allow students to progress at their own rates. It provides a means, and even suggests the need, for breaking away from the lock-step system of advancing students once or twice a year. However, when the full range of factors involved in an organizational plan is considered--the spatial arrangements, the student-scheduling problems, the versatile and effective use of teachers and other resources--the problem of design becomes overwhelming.

At his present level of capability for designing school organizations, the educator formulates a relatively simple plan, tries it in a real school, observes the problems as they arise, and attempts solutions on a piecemeal basis. It is in this fashion that schools have been designed in the past, and it is the pattern that will be followed in the future unless new solutions can be found.

Complex institutional innovations are not only conceptually overwhelming, they are often very expensive, and in the real-life situation almost always require long periods of adjustment in which disappointingly small increments are made in reaching objectives.

Simulation techniques provide a possibly much-improved alternative. With a sufficiently sophisticated simulation technique, innovations can be tested as if they were actually installed in the system under study. It is possible, then, to make actual changes which are far more likely to have anticipated the problems which innovation presents to the system.

The people who build the simulator must keep in mind that their simulator will be an expression of their theories about how the actual system operates. They wisely make provision for comparing their simulations with the real world and make provision in the simulation system itself for altering their theories and the means used to express them.

The Education and Training Staff at System Development Corporation in Santa Monica, California, has been engaged, since 1958, in intensive experimentation in the area of computer-based instruction and the methodology for development of instructional materials. Support from the United States Office of Education in 1963 permitted the staff to focus additional resources upon the possibilities of finding new solutions to programs of school organization through system analysis and simulation.

2. The SDC School Simulation Project (1)

The SDC School Simulation Project, which uses the techniques of systems analysis and computer simulation, should yield methods and provide design recommendations that are more carefully conceived, that involve more pervasive and integrated changes throughout the schools, and that employ instructional media more effectively than do current school-design methods.

It should be noted at the outset that the SDC project is not concerned with the equally important areas of educational data processing involving financial control and property management. Neither is it directed toward master schedule-student program problems already receiving attention from several major study groups.

In order to give a specific objective for the project's immediate outcomes, the high school is the basic unit for investigation in the study. Four major steps or procedures are involved in the project: (1) survey and selection of high schools; (2) system analysis of five high schools selected for study; (3) construction of a computer-simulation vehicle that will provide the capability of building detailed, dynamic models of the schools and of testing hypothetical changes in the schools; and (4) simulation and study of the five high schools with the simulation vehicle.

The survey and selection of schools, and the system analysis of the schools selected are primarily the responsibility of

Dr. John S. Cogswell, Human Factors Scientist, Education and Training Staff, SDC, project head,

Mr. Jack Bratten, Human Factors Scientist, Education and Training Staff, SDC, and

Dr. Robert L. Egbert, Chairman of the Department of Graduate Education, Brigham Young University (Utah), consultant.

The construction of a school simulation vehicle is the responsibility of

Dr. Frank A. Yett, Associate Professor of Mathematics and Chairman, Computer Sciences Department, Pasadena City College (California), consultant, and

Mr. Donald G. Marsh, Senior Programmer Analyst, Education and Training Staff, SDC.

Computer simulation of the selected high schools and analysis of innovations throughout the spectrum of school organization which the schools represent is proceeding as a team effort.

3. Construction of the School Simulation Vehicle (1)

The simulation vehicle is designed to meet the following specifications:

1. The capability of building dynamic models of real or proposed high schools.
2. The capability of flexibly modifying the models to represent different design configurations.
3. Detailed recording of the events that take place during the simulation.
4. The production of detailed output data that reflect the effects of various design changes within the model.
5. The simulation of events occurring in relation to time.

4. Design Objectives of the Vehicle (1)

The simulation vehicle has been constructed so that a high school can be described in terms of school characteristics (resources, organizations, procedures, etc.) and student characteristics that bear on the school's instructional plan; for example:

a. The curriculum and its organization.

b. The availability of instructional and non-instructional space.

c. The resources such as programmed learning materials, teaching machines, equipment, teachers, counselors.

d. The procedures for sequencing students through the instructional system.

e. The procedures for channeling students through the counseling system.

f. The procedures for admitting and terminating students.

g. The procedures relating to external agencies directly concerned with helping students.

h. The information-processing procedures.

i. The characteristics of the students that relate to the instructional and counseling process.

j. The decision-making procedures.

The vehicle is programmed in the JOVIAL programming language for the Philco S2000 computer. It is constructed in modular form so that a model of an existing or proposed school can be constructed by assembling the modular parts into a particular configuration.

Although the high school has been selected as a specific target for the project, the vehicle reflects the criterion of <u>modular generality</u>. The expression of the vehicle, the method of its construction, and the provision for alteration of the vehicle provide the means by which the vehicle could be used to study organizational problems found in elementary as well as collegiate institutions.

5. General Structure of the Vehicle (2) (3)

The organizational plan of the school is expressed in that part of the vehicle which is called the Activity Processor (AP). The allocation of resources and assignment of resources to the AP takes place in the Resource Allocation Processor (RAP).

All events taking place are expressed in terms of discrete activities which can take place when the required resources are made available. There are three classes of resources: persons, places and things. An activity requires at least one resource from each of the three classes of resources.

Reservation of the resources assigned a particular activity is made for a number of time units, defined in present models of the vehicle as 1/8 of an hour.

6. Control of Time (3)

Time duration in the simulation vehicle is expressed on two time scales. The time scale for the Activity Processor is a series of time units of equal duration, logically connected end to end, ad infinitum. All activities begin at the start of a time unit and terminate at the end of a time unit. From its beginning to its end, an activity is said to be underway. During the time in which the activity is underway the resources engaged by the activity undergo no change. Changes in the status of resources take place when the activity is deactivated.

The Resource Allocation Processor operates on a time scale considered as a series of "suspended" or "null" periods interspersed between successive time units of the Activity Processor. During each such null period, completed activities are deactivated, new activities are made ready for activation in the next time unit of the Activity Processor, and activities which will be underway in the next time unit are continued.

7. Resources (4)

The provision of resources (persons, places and things) is viewed by the school simulation vehicle as the sine qua non for activity in the system. Available resources are assembled by the Resource Allocation Processor in order to place activities underway.

Whether or not the RAP will place an activity underway, depends upon the availability of all of the resource(s) required. Sensitivity to the control and distribution of resources is effected in the vehicle by the status of the required resource. The statuses of resources are defined below.

Out-of-system - A needed resource that does not exist in the system, or will not exist in the system at the time projected by an activity demand (indicating that current scheduling will exhaust the supply before the activity demands the resource).

In-system - A needed resource that does exist in the system, or will exist in the system at the time projected by an activity demand (indicating that current scheduling will introduce the resource before the activity demands the resource).

In-system resources may be either: In-use
Not-in-use

In-use - An in-system resource that is now engaged by an activity or will be engaged at the time projected by an activity demand.

Not-in-use - An in-system resource that is not now engaged by an activity or will not be engaged at the time projected by an activity demand.

In-use resources are classified as: At-capacity
Below-capacity

At-capacity - An in-use resource engaged by an activity at full capacity.

Below-capacity - An in-use resource engaged by an activity at less than full capacity.

Below-capacity resources are classified as: With-reserve
Without-reserve

With-reserve - An in-use, below-capacity resource, the reserve capacity of which is available for additional activity demand.

Without-reserve - An in-use, below-capacity resource, the reserve capacity of which is not available for additional activity demand.

Not-in-use resources are classified as: On-shelf
Out-of-service

On-shelf - A not-in-use resource that is available for activity demand.

Out-of-service - A not-in-use resource that is not available for activity demand for some reason other than in-use; for example, lost, defective, etc.

Resources must be in one of two available statuses for use by an activity: in-use, below-capacity, with reserve, or not-in-use, on shelf.

8. Simulated Resource Demands (5)

Early versions of the School Simulation Vehicle have assumed that, except for the student or students required for an activity, the system has available an infinite reservoir of resources. Under these assumptions an activity can be placed underway whenever the appropriate student cadre has been formed.

Present versions of the Vehicle continue this assumption but are provided tables which are used in post-run analysis to assess the resource demands made by the system when simulating a particular school.

These tables are:

List R, Resources Available to the System

List C, Resource Call by Each Activity of the System.

List R includes the categories of persons, places and things. Persons available as resource to the present versions of the vehicle are:

Students (as individuals)
Groups of students (by subject)
Counselors
Clerks
Teachers (of individual students)
Teachers (of groups of students)

In present versions of the vehicle the user may use three categories of students, each with as many as 1000 students. Typical codes for students are:

111077 a Type 'A' student, number 077
112013 a Type 'B' student, number 013
113415 a Type 'C' student, number 415

The simulation of student populations with a broader range of characteristics is discussed in the section, "Simulating Student Populations." The methodology used in the computer program described in that section will be incorporated in later versions of the vehicle.

Places available as resource to the present versions of the vehicle are:

Individual instruction or study spaces
Group instruction or study spaces
Counseling task places
Clerical task places
Teacher task (excluding instruction) spaces

Things available as resource to the present versions of the vehicle are:

Task packets for individual students
Task packets for student groups
Counseling task packets
Clerical task packets
Teacher instructional task packets
Teacher task packets for other than instructional tasks

List C includes a detailed resource call for every activity of the system. Examples used in a recent model were:

Counseling Appraisal activity

A counselor
A counseling task space
A counseling task packet

Review Counseling Recommendations, Subject Alpha

A Subject Alpha teacher (of individual student)
A non-instructional teacher task space
A non-instructional teacher task packet

Group Help, Subject Beta

A Subject Beta group of five students
A Subject Beta teacher for groups
A group instruction space
A student group task packet
A teacher instructional task packet.

Resources are reserved for an activity during the time in which that activity is underway. A resource unit is defined as the engagement by an activity of a resource for one time unit.

For example, if a student were scheduled for an Individual Help activity which was underway for seven consecutive time units, the resource call for that activity would be:

7 student (individual units
7 teacher (of individuals) units
7 individual instruction space units
7 student task packet units
7 teacher instructional task packet units

or 35 resource units in all.

More than one student may be engaged in an activity during any time unit, and students may be engaged by that activity for varying periods of time. For example:

Time unit	942	943	944	945	946	947	948	949	950	951	
Student											
112013	x	x	x	x							4
111056		x	x	x	x	x					5
111077		x	x	x	x						4
113415			x	x	x	x	x	x	x		7
112047			x	x	x	x	x				5
111613							x	x	x	x	4
Total	1	3	5	5	4	3	3	2	2	1	29

The resource call of activity for the 10 time units, 942 to 951, would be:

13 Type 'A' student units
9 Type 'B' student units
7 Type 'C' student units
29 teacher (of individuals) units
29 individual instruction space units
29 student task packet units
29 teacher instructional task packet units

or 145 resource-units in all.

The tabulations above exemplify the resource calls made by all activities.

9. Activities (1) (2) (6)

Events which take place are logically related in the Activity Processor (AP). The flow characteristics of the AP are expressed with flow charts constructed from a hierarchy of functional constructs or modular units of varying degrees of inclusivity. From the most inclusive to the least inclusive, the constructs are:

- system
- module
- package
- procedure
- activity

In present versions of the vehicle the most detailed level of description is made with the activity. Activities are combined to constitute procedures. Procedures are combined to make up packages. Sets of packages are combined to form modules. And finally, the assembly of modules defines the total system that is being simulated.

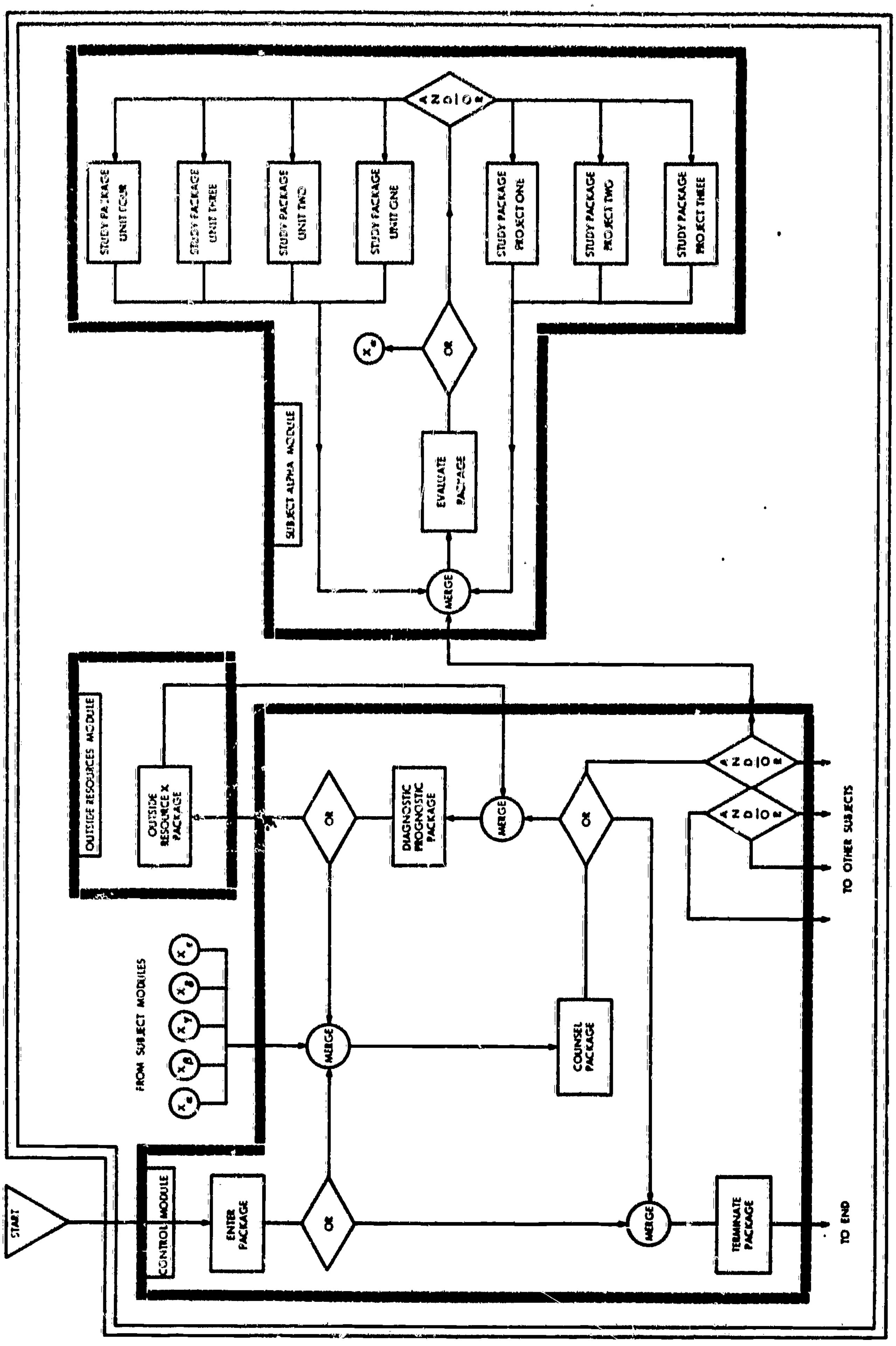

Figure 1. A typical system using the School Simulation Vehicle.

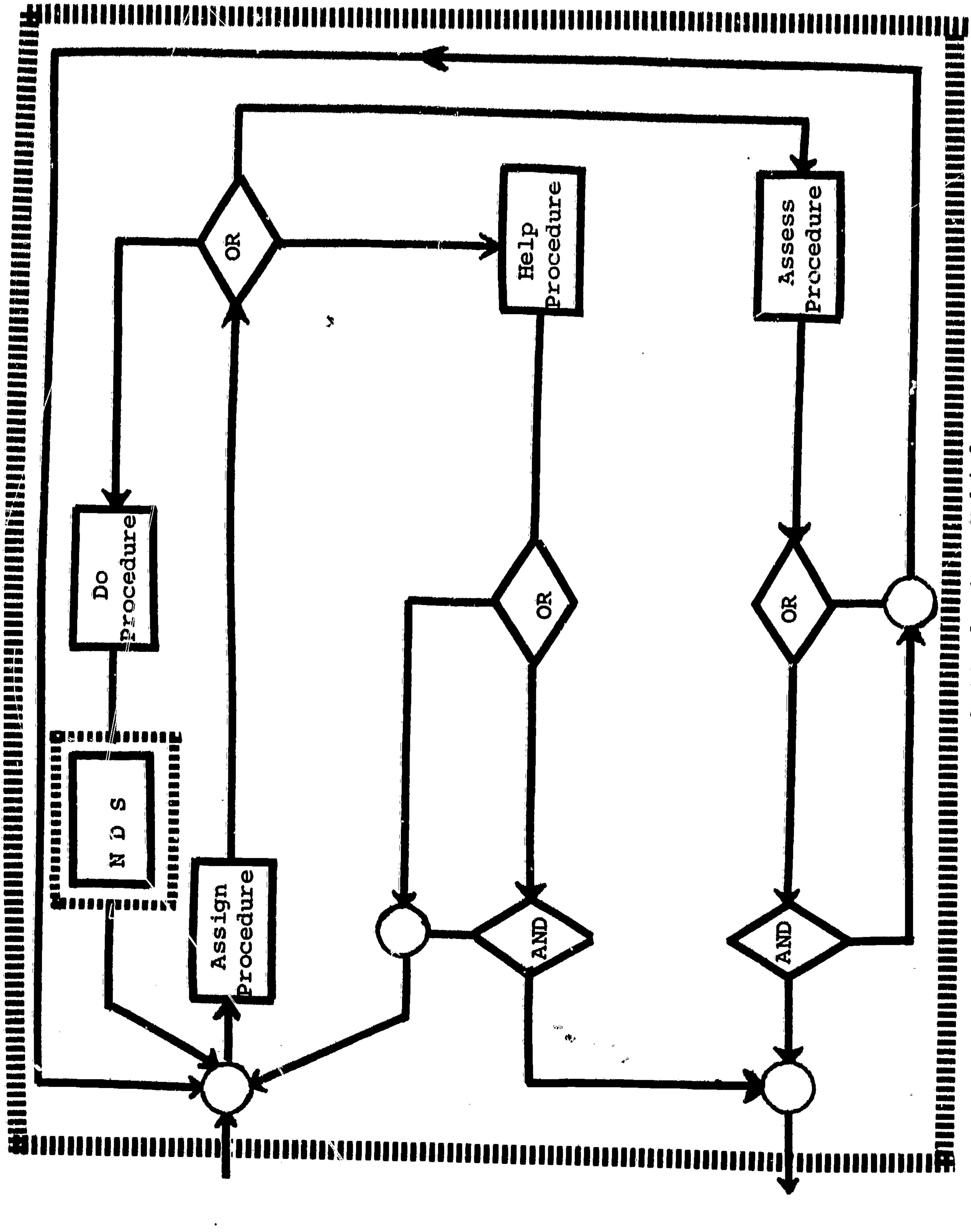

Figure 2. The School Simulation Vehicle of the Study Package.

A typical system is shown in Figure 1. It consists of a Control module, an Outside Resources module and the number of Subject modules which the user finds necessary to simulate the particular school he has in mind.

The Control module includes four packages: Enter, Terminate, Counsel, and Diagnostic/Prognostic. The Enter and Terminate packages can be used to simulate such procedures as admission, registration, graduation, withdrawal or dismissal.

The decision box following the Evaluate package in Subject Alpha shows the alternative (X_a) which feeds into the Counsel package of the Control module. The Counsel package can be used to represent counseling activities. Students might be referred for interviews by the teacher. A report of a student's subject performance may alert the counselor to the necessity of a counseling interview, in which case he has the student diverted from his regular study activities.

Each of the Subject modules consists of an Evaluate package and the number of Study packages necessary to simulate the curricula. Each of the Study packages consists of four procedures: Assign, Do, Help and Assess.

Figure 2 shows the Study package. Various patterns of activities can be simulated by varying the flow of students within the Study package and its constituent procedures. Students may be assigned "do" activities individually or in groups of any size. By variation of the cyclic patterns within the Study package any study task can be simulated. After completion of an assignment, students can be given another assignment to be done in a different mode or in a different course. They can be simulated getting help from some teaching resource; or the simulation can entail students being assessed in some fashion. Following the assessment, students may be given help or they may be assigned a new study activity.

Subject Alpha is comprised of seven Study packages and one Evaluate package. Subject Alpha is shown as having four units of work and three projects. Each of the units and projects is described in the simulation model by varying the flow within the Study package. Project One could be specified as a laboratory unit, a field trip or a research project, whereas Unit One could be individual study in a student carrel or a lecture-discussion period of twenty students.

The Evaluate package includes the decision rules that a teacher would use regarding the flow of students in their study activities.

Activities are included for collecting and classifying pertinent records of the student's activities and planning reviews of student performance. Review of student performance in study activities, accommodation of counseling recommendations, and the reactions to the effect of particular subject activity on the student's entire program of study may be simulated.

The Diagnostic/Prognostic package contains a set of decision procedures for planning the referral of students to outside agencies such as a child guidance clinic. In Figure 1 the outside agency is represented by the Outside Resources module. Although the system in the example does not fully represent a school system, it does illustrate that a system can be modeled by assembling the modular units available to the user of the vehicle.

10. Classification of Activities in the Activity Processor (3)

The Activity Processor includes all the activities necessary to express the simulation during the time unit, i, whether or not the activity is actually underway. These activities represent a subset of all possible activities which the simulation vehicle implies by reason of its logical expression.

All the activities in the Activity Processor during any time unit, i, are considered to be on the:

Active List including all those activities underway during time unit i, or the

Dormant List made up of all those activities which have been made ready by the Resource Allocation Processor prior to the beginning of time unit i, but which are not underway because some required resource could not be provided at the time the activity would have otherwise begun.

11. Classification of Activities in the Resource Allocation Processor (3)

Figure 3 illustrates the relationship of the several activity lists of the Activity and Resource Allocation Processors.

At the end of time unit i, the Activity Processor operation is suspended, and the Resource Allocation Processor is activated. All the activities listed on the Dormant List, time unit i, are transferred to the:

Interim List made up of all those activities which may be placed underway in the next time unit, i+1, provided resource criteria are met.

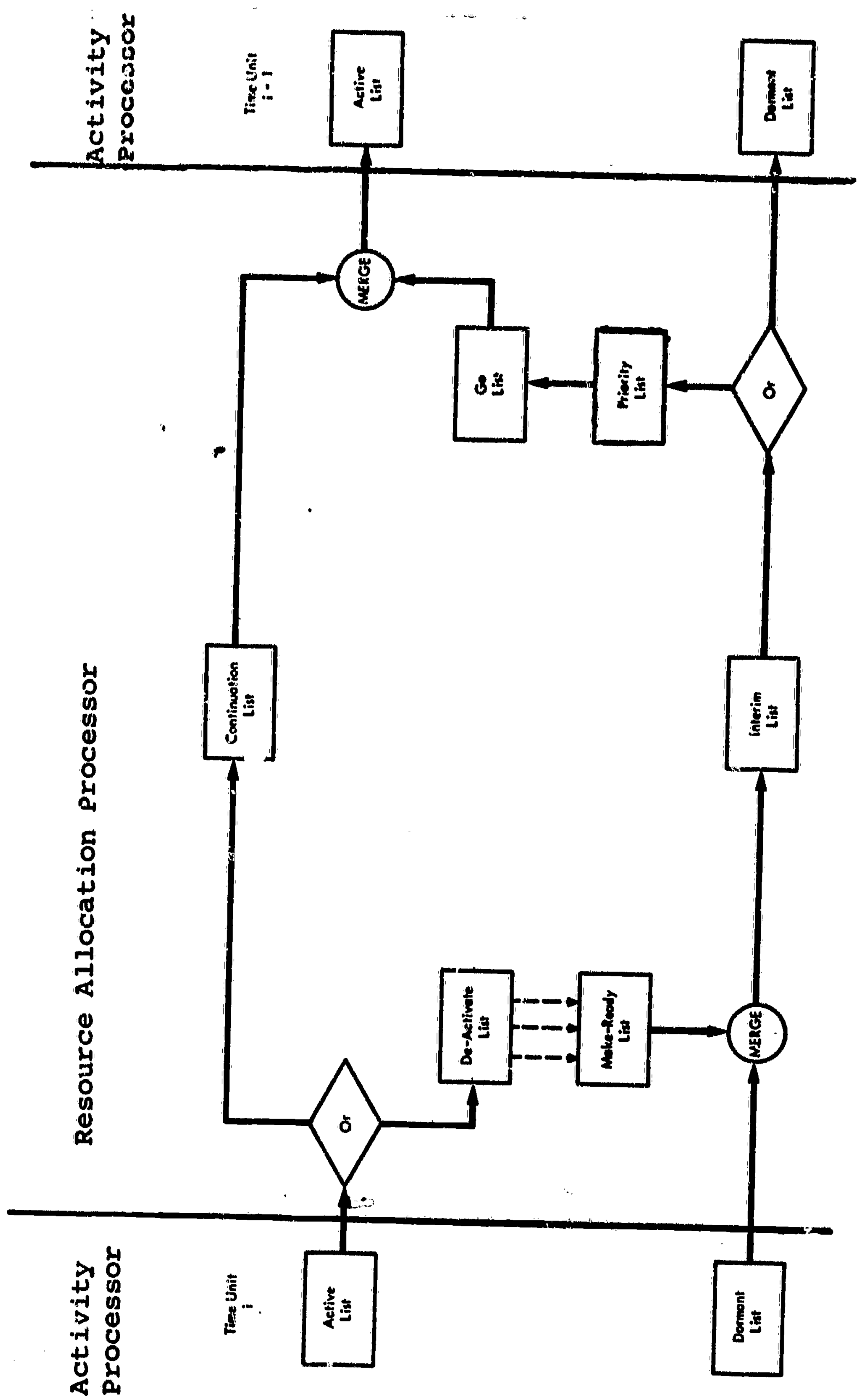

Figure 3. Activity Lists in the School Simulation Vehicle

All the activities on the Active List, time unit i, are reviewed. Those activities which have not been terminated with the end of time unit i are transferred to the:

Continuation List - which is made up of all those activities which will continue underway during time unit i+1.

Those activities which have been terminated with the end of time unit i are transferred to the:

Deactivate List - which includes all those activities which have been terminated at the end of time unit i.

The Resource Allocation Processor assigns the released students to "next" activities. If a next activity is not already on the Interim List (having been transferred from the Dormant List, time unit i), such an activity is made ready and placed on the:

Make-Ready List - including all those activities required by the distribution of students from deactivated activities, but which have not been previously made ready.

The activities on the Make-Ready List are transferred to the Interim List which has previously received activities from the Dormant List, time unit i, thus completing the Interim List. Activities on the Interim List to which a sufficient number of students cannot be assigned, are placed on the Dormant List, time unit i+1. Those activities on the Interim List which have the requisite students are placed on the:

Priority List - made up of all those activities arranged according to priority rules for placing activities on the Priority List.

The user can at this point in the vehicle specify the placement of certain activities or classes of activities at the head of the priority list. In present versions of the vehicle, priority is simply first in-first out.

The system resource capability is reviewed for the resource demands of each activity on the Priority List, in order of the priority established. All those activities for which the system cannot supply the required resources are placed on the Dormant List, time unit i+1.

Those activities which the system can supply with the required resources are placed on the:

Go List - made up of all those activities which can be placed underway beginning time unit i+1.

The Go List and the Continuation List are combined to form the Active List, time unit i+1.

With the transfer of activities to the Active List, the cycle of resource allocation based on the simulation of time unit i is complete. The Activity Processor is activated for time unit i+1 and all the activities on the Active List, time unit i+1, are placed underway.

12. Time-Based List Processing (6)

The Active List of the Activity Processor includes all those activities underway during time unit i. Associated with each activity underway during time unit i is a binary number of zero's and a "1." The "1" is located in the code number, reading from the left, a number of places from the leftmost digit equal to the number of AP time units, from time unit i, in which the activity will terminate.

Expiration at End of AP time unit	Associated Binary Code Number
i	10000...
i+1	01000...
i+2	00100...
...	...

The RAP is concerned only with deactivation and subsequent processing of those activities which have the code number, "10000...," of record.

The Go List of RAP is made up of all those activities which can first be placed underway beginning time unit i+1. When placed on the Go List, an activity is assigned a binary code of zeros with a "1" placed "j" places from the leftmost zero digit, where "j" is the duration of the activity in AP time units.

Duration in AP Time Units	Assigned Binary Code Number
1	01000...
2	00100...
3	00010...
...	...

When the Go List is completed, the activities of this list and those of the Continuation List are combined to form the Active List of AP for time unit i+1, and RAP prepares to relinquish control to AP.

Routinely, immediately prior to relinquishing control at the end of the null period following time unit i, the RAP shifts one place to the left the digit "1" of the code number of all activities on the Active List. All activities which will terminate at the end of the next AP time unit will then have the code number, "10000...," and the time-based list processing cycle is once again ready for the RAP assumption of control at the end of the next AP time unit.

Preliminary statements have been prepared for incorporation in later versions of the vehicle which will process the demand for all resources directly in the simulation run. The time-based list processing technique will be used to process resources categorized in the manner described in the section, "Resources."

System control of resources will then be effected by input parameters regulating the kind and amount of resources made available to the system and the processing of time-based listings.

Present versions of the model use, for all resources except students, the techniques for simulating resource demands described in the section, "Simulated Resource Demands."

13. School Study Patterns (8)

Certain characteristics in the study program of an individual student are common to all types of school organization. One which suggests itself is that each student will have in his program of study some three to six subjects.

In a familiar pattern, the school may organize its subject offerings by assembling some fifteen to forty students in successive, normally invariant, weekly cycles of hourly classes. In a not-yet-realized, individualized, continuous progress plan, the school might achieve a complete freedom from pre-arranged schedules in which each student not only may have a unique sequence of classes, but also may require a different pattern of subject attention from day to day.

In the latter plan, as well, hourly classes might be the exception rather than the rule. The student might concentrate upon a subject for a few minutes to several hours in a single time period. Nonetheless, every student would be responsible in these contrasting plans for achieving a satisfactory performance in several subjects, and attention to any one of the subjects would be intermittant and in some manner cyclic.

Subject attention patterns aside, the two types of schools look very much alike. Assignments must be made and completed, help must be given, tests must be taken, and evaluation and counseling must take place. Students in every school require the provision of resources; what each student does has its effect, large or small, upon other students and the teachers and staff.

The School Simulation Vehicle is designed to permit the modeler to specify a logical flow of defined operations which validly simulate school organization throughout the spectrum whose range is determined by the contrasting patterns described above.

14. Individual Study Activities (8)

As the student follows his program of study in the continuous progress plan, he has an unpredictable sequence of activities to perform. The activities are classified and defined, but the pattern of activities which is appropriate on his part is unknown prior to the effort.

The model, then, must be ready to respond to the individual program of study and provide the modeler with the means by which intermittant but cyclic patterns of study can be made to conform to the school's organization.

The means by which the vehicle provides this responsivity is the "Next Do Procedure Selector."

15. Next Do Procedure Selector (NDS) (8)

The Next Do Procedure Selector (NDS) is a programmatic device for making each student's program of study a unique program, should the school's organization call for this flexibility.

NDS routes the student from one subject to the next by permitting the vehicle to process the student, as dictated by the logical flow of the model, until the student completes a study activity in the Do procedure of the Study package of current subject assignment. Control is then assumed by NDS.

NDS, upon assuming control, is first concerned with selecting an Applicable Next Scheduling Integer (ANSI). ANSI is used to assign the next subject which will be assigned to the student's work load in conformance with a set of assignment rules. The rules may include a simple sequential selection from the applicable set of ANSI integers. More generally, NDS extracts integers from a table of integers, by some sampling technique, until an applicable next integer is obtained. If the student has n subjects in his program of study, the applicable set of integers is $\{0,1,2,\ldots, n\}$.

The usual expectancy is that the rules will permit the use of any applicable integer selected. However, that integer may not be next usable. Perhaps the rules do not permit the same ANSI to be used twice in succession, or require that some particular integer be next selected after some elapsed time, or after some number of other integers have been selected and used.

The digit "0" represents a unique choice. Should "0" be selected, the student is credited with having accomplished some number of study activities in one or more of the subjects in his program of study. This "extra" effort represents "homework" or "out-of-assigned location" effort.

The incrementation of the number of study activities is limited in any case so that the number of completed activities is no more than one less the number required for the unit of study affected. A unit of study, therefore, is always completed by normal processing of the student in the appropriate Study package.

16. Group Study Activities (9)

The vehicle is equipped to simulate the hour-by-hour, subject-by-subject program of groups of students in a lock-step pattern, as well as *ad hoc* formation of groups in a continuous progress plan. The vehicle provides this flexibility by offering a choice upon entry to the Do, Help and Assess procedures of the Study package. At these points either individual or group activities can be selected.

17. Group Activity Simulators (9)

Group activities are organized in the simulation by a group activity simulator. Present versions of the vehicle include Group Help (GHS), Group Assess (GAS), and Group Study (GSS) simulators. The flow characteristics of the three simulators are identical. The following description of the Group Help Simulator will serve to describe the Group Assess and Group Study Simulators.

The student is imagined to be occupied in his studies and as such is "located" in a Study package. If the student, within the study cycle of a particular subject, is next assigned to group help, a request for group help is filed for the student. Instead of waiting for the assembly of a group, the student is branched to the Assign Procedure of his current subject. This activates the Next Do Procedure Selector which assigns the student to an alternative subject.

At the end of every 3kth AP time period, the Resource Allocation Processor places the Group Help Simulator in control for processing the group help requests accumulated in the 3k periods. (The GAS is activated k periods after each GHS analysis, and the GSS is activated 2k periods after each GHS analysis.) If group help requests are on file, a search is made using criteria for group formations. Obvious criteria are subject, unit of study, and group size, but others will occur to the model user. If a group can be formed, the group is placed on the GHS priority list and the requests of the member students are removed from the file.

The searching for groups continues until a complete search of the file is made during which no group can be formed. If unfilled group help requests remain on file, these are examined for those requests which now exceed a time limit imposed by the model user. Those requests which now exceed the time limit for waiting are processed as if they were group sessions and are placed on the GHS priority list. The remaining unfilled requests are kept in file for the next 3k AP time periods when the GHS will again be placed in control during the RAP interval.

Following the formation of groups, each group on the GHS priority list is examined using criteria which govern the "capacity" of the system. Using these criteria, the total number of group sessions which can be formed might be less than the number of sessions ready for processing within the next 3k time periods of the Activity Processor. Those group help sessions which are in excess of capacity are removed from the GHS priority list, and the member student requests are re-filed for re-examination in the GHS analysis 3k time periods later.

If the projected group help is not in excess of capacity (however defined), the GHS records the activity in each member student's record and confirms the activity for processing.

Those group activities which are confirmed for processing are placed on the Make Ready list of the RAP and subsequently placed underway in the next AP time period. The member students will be engaged in the group activity for the requisite number of AP time periods. When the GHS priority list is thus reviewed, GHS relinquishes control.

If the student assigned to a group activity would have started some other activity at the time of assignment to the group, the other activity is placed on a <u>deferred</u> status. If the student is engaged in some other activity at the time of assignment to a group, the other activity is placed in a <u>suspended</u> status. In either case, the student will be returned to his interrupted sequence of activities upon release from the group activity.

Appropriate control of deferred or suspended activities is maintained by the Resource Allocation Processor.

18. Number and Time of Activities Variation (10)

Organization and control of activities in the simulation of institutional behavior is provided the School Simulation Vehicle by the Activity Processor (AP), the Next-Do Procedure Selector (NDS), and group activity simulators.

Organization and control of the provision of resources (persons, places and things) is provided by the Resource Allocation Processor (RAP) using the techniques of Time Based List Processing (TBL).

Responsitivity to the traits of persons engaged in the defined activities of the system is made possible by the description of each person with a finite number of traits, each trait in turn described by a limited number of differentiating descriptors. The vehicle methodology for simulating population is described in the following section, "Simulating Student Populations."

One would expect members of the population set to have distinguishing characteristics and also to find differences in their performances. Student performance can be thought of as response to an assigned objective. The objective is attained by the performance of many activities. It is assumed that a range of achievement levels will be realized by students, and that students will "put together" almost unique sets of activities when attempting to complete common objectives.

These assumptions require an expectation that both the number of activities performed and the time required to complete similar study objectives will vary from one student to another, as well as in successive performances of the same student.

To accommodate these assumptions the School Simulation Vehicle permits the modeler to characterize activities with four kinds of variation.

One variable is time. For example, two students are assigned the objective of exceeding a certain score on a subject test. A log of activities is kept for each student. One student takes several hours to complete his activities and to take the test; the second student takes less than an hour. Let us assume that their acceptable scores are very nearly the same.

Another variable is the number of activities performed. The logs may reveal that one student performed 112 activities and the other performed 87 activities, and to compound the variability, that the students performed similar activities in different amounts of time.

A third variation is evidenced by the fact that each student has performed activities which the other has not performed. Finally, the order in which common activities have been performed differs. There are common sequences of activities, but in some part the logs show differences in order.

Provision for variation in the order in which activities are performed and differing patterns of activities have been described. These variations are provided by the Activity and Resource Allocation Processors.

Variation in performance time and the number of study activities required for the attainment of an assigned objective are provided in the RAP by the formulas for Number and Time of Activities Variation (NTV).

When the Resource Allocation Processor is ready to place a next activity on the Make Ready list, the time variation formula is used to assign a time duration of some number of time units to that activity. A particular activity, for example, might require, on the average, 7 time units to complete. The application of the formula to that activity might result in time duration assignments of perhaps from four to ten units, depending upon control parameters used by the formula.

The number of activities variation formula is used to determine the number of cycles which the student must complete within the Do procedure of the Study package in order to achieve his assigned objective. In the section, "Activities," it was noted that variation in the flow of activities within the Study package was possible. The key element of the activity pattern in the Study package is the completion of the study activity within the Do procedure. Achievement of a study objective is signalled by the completion of an assigned number of these cycles ending with the completion of the Do procedures.

The average number of "Do's" required by the population set from completion of a certain unit might be 25. Application of the formula, in the case of a particular student or group of students, might result in an assignment of perhaps from 18 to 32 Do's.

The time and number variation formulas have the same form and consist of two addends. One addend provides for variation as a function of the characteristic of the student or group of students assigned to the activity. The second addend provides for variation of the same or similar task by the same individual or group of students. Provision is made for influencing the formulas by reason of changes in the resources of the system as well.

19. Simulating Student Populations (11)

One of the most important attributes of the simulation vehicle is its responsivity to the traits of the person(s) engaged in the defined activities of the system.

In the present versions of the vehicle, the methodology of population production for simulations in the model is applied only to students. The methods used, however, will apply equally well to staff.

The vehicle requires each person be described by a finite number of characteristics or traits, and each trait in turn described by a limited number of differentiating descriptors or archetypes.

A trait is a set of related descriptors. Descriptors are discrete estimates made of the trait on some step scale. Descriptors represent measurable differences within the trait family. For example, the trait, sex, is described by the descriptors, male and female. The trait, age, might be described by the number of months or years the person has been living, or the number of months or years since his entry to the system.

Traits may be physical or mental measures or attributes derived from potential or actual achievements and performances that occur both prior to entry and within the system. Traits also may be physiological descriptions or descriptions derived from psychological constructs.

Each of the unique sets of descriptors (one descriptor from each trait) which can be assigned to describe an individual in the population is defined as an archetype.

For example, suppose that the population is characterized by three traits, A, B, and C, each with two descriptors:

$$A = \{1,2\} \qquad B = \{\#,\$\} \qquad C = \{x,y\}$$

Then eight unique archetypes are defined:

(1,#,x)	(1,#,y)	(1,$,x)	(1,$,y)
(s,#,x)	(2,#,y)	(2,$,x)	(2,$,y)

and every member of the population must be one of these types.

The computer program, Population Simulator (POPS) is used by the vehicle to generate a population of individuals. An archetype is selected for the individual from a set of five traits, each described on a scale of ten descriptors.

The POPS program distributes archetypes in the population using two classes of criteria:

1. Within-trait criteria. Criteria by which distribution of the trait descriptors among members of the population is developed,

   a) probabilistically from a specified distribution,
   or b) exactly from a specified distribution. These are called Alpha Criteria.

2. Between-traits criteria. Criteria by which, except for the initially specified trait, assignment of descriptors (from a specified distribution) is contingent upon the assignment of descriptors from previously distributed traits. These are called Beta Criteria.

When the simulation involves the modeling of system processes that respond differently to characteristics of members of the population, precise control of population specifications may be critical in certain parts of the system and spell the difference between successful and unsuccessful design.

The model builders anticipate that specific hypotheses about system response in certain areas will be a major concern to users of the model. For example, it may be of interest to measure the demands upon the resource capability of the system if some particular type of individual is predominant in a group of prescribed activities.

Within the limitations of the POPS program, data from samples of students in selected schools can also be used to describe the students for a simulation study.

20. Output Displays (12)

The output data generated by the simulation vehicle is a time-based record of every discrete activity which has taken place during a simulation run. Output displays are selected sequences of values prepared from that output data.

Output displays are of two types:

Tabulations of the occurrence of activities.
Tabulations of resources required for effecting activities.

The occurrence of an activity may be represented by tabulating the number of times the activity has been effected or by the length of time the activity has been underway. Output displays of resource requirements are obtained by referencing tables of resource demands established for the particular vehicle modification in use.

In present versions of the vehicle the assumption is made that, except for students, any required resource is always available. Following a simulation run, therefore, the resources which would have been required to effect the simulation can be determined by using List R to tabulate the resource demands of each activity placed underway in the simulation run. List R is described in the section, "Simulated Resource Demands."

The output data record of the simulation run is the direct source of output displays which tabulate the number of occurrences of some activity. For example, how many times during each of the four weeks of the first month did the Counseling Appraisal activity take place? A search of the output record would result in the tabulation of four values, for example: 23,15,12,18.

Table 1 is the table display of that information.

Table 1

Display 123

Number of
Counseling Appraisals by Counselor
for
First Month of Semester by Weeks

1st Week	2nd Week	3rd Week	4th Week
23	15	12	18

(By referring to the resource demand for Counseling Appraisal activity, the user notes that the person resource called by that activity is identified as "counselor.")

The user might find little need to make a table, knowing from his specification what the four values of the output display represent. In reporting this information to others, however, he might decide that such a table display is the simplest device with which to inform his reader of the meaning which should be attached to the four values.

The user of the model specifies output displays using a code developed for the purpose. The code provides for specifying the number of occurrences or the number of time units of any class of activity during any portion of the simulation run. For example, a display might consist of the total number of time units a certain activity was underway during the first 1000 time units of the simulation run, during each 100 consecutive time units of the entire simulation run, or during every 48th time unit, the intervening 47 units being ignored.

The output display specification takes the form:

ODnnn: (Value); (Entry); (Time)

Using the codes available for (Value), (Entry) and (Time) the user would specify the following for the output display used in Table 1:

OD123: (N) ; (List A: 1221) ; (Time: M,W)

"N" indicates that the number of occurrences will be tabulated. List A: 1221 identifies the activity, "Counseling Appraisal," and "M,W" specifies that "N" will be found for each of the four weeks of the first school month of the simulation.

(List A is a detailed list of coded numbers with which every class of activity, and every activity within the class, can be identified for output display purposes.)

Appropriate specification for displays serves as a device by which the user tests not only his view of the simulation, but the performance of the vehicle under imposed rules. When specifying output displays, the user will usually avoid requesting displays which are clearly null. The user may know, for example, that decision rules he has imposed upon the vehicle will negate choices at decision points provided by the vehicle.

Yet, null values may serve useful purposes in the analysis. A "0" may indicate that intended outcomes at certain decision points are not taking place, when in fact, the user is convinced that such outcomes should be the case.

On the other hand, the display of values other than "0," for entries which should be "0," may indicate to the user that activities are taking place contrary to rule, or that the input criteria are incorrect. Instead of asking for the status of some activity in each of the "hours" of an entire semester, he could sample that status by specifying a certain hour in each week, or the hours of every fourth week.

Because the user has at his disposal the specification of any sample of time "blocks," he can conduct preliminary analyses of the output record on a highly attenuated basis. Results of a particular phase of the simulation, which he expects to result in a very large number of values, may be sampled by the appropriate code specification.

Major attention is also given by the user of the vehicle to the description of student behavior developed by a simulation for a particular school organization. The vehicle routinely provides an activity-by-activity record of each student's activities, called the Tracer File.

This file of data will be a part of a larger file of record for each student, the "Student Cumulative File," as yet under development.

21. Use of the Vehicle

The first three phases of the SDC project:

Survey and selection of high schools;
System analysis of selected high schools;
Construction of the vehicle;

are now in the final stages of completion. Plans for simulation of the selected high schools and the introduction of simulated innovations are at this time ready for effecting an extensive program of simulation runs.

The procedure to be followed will be to work back and forth between simulated data and data obtained from the selected schools. It is predicted that the correspondence between the data obtained from the environment will increase with continued study. The test of validity will be met if users of the vehicle can change the organization within the model and obtain predicted effects that later are substantiated by the same sequence of events in the real environment. It is toward this end that the simulation studies of the SDC project are directed.

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