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

ED 012 096 EA 000 524

SOME RESULTS OF A SIMULATION OF AN URBAN SCHOOL DISTRICT.

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REPORT NUMBER R-042467 PUB DATE 30 MAR 67
EDRS PRICE MF-$0.18 HC-$2.72 68P.

DESCRIPTORS- *COMPUTERS, *MODELS, *SIMULATION, *URBAN SCHOOLS, SCHOOL DISTRICT SPENDING, FINANCIAL POLICY, ADMINISTRATIVE POLICY, TABLES (DATA), *OPERATIONS RESEARCH, COMPUTER PROGRAMS, RESOURCE ALLOCATION, COMPUTER ASSISTED INSTRUCTION, PHILADELPHIA,

A COMPUTER PROGRAM WHICH SIMULATES THE GROSS OPERATIONAL FEATURES OF A LARGE URBAN SCHOOL DISTRICT IS DESIGNED TO PREDICT SCHOOL DISTRICT POLICY VARIABLES ON A YEAR-TO-YEAR BASIS. THE MODEL EXPLORES THE CONSEQUENCES OF VARYING SUCH DISTRICT PARAMETERS AS STUDENT POPULATION, STAFF, COMPUTER EQUIPMENT, NUMBERS AND SIZES OF SCHOOL BUILDINGS, SALARY, OVERHEAD COSTS, AND INFLATION EFFECTS. PAST AND PRESENT VALUES OF THESE PARAMETERS ARE USED TO CALCULATE FUTURE TRENDS. ADMINISTRATIVE DATA WHICH LIMIT THE MODEL ARE STUDENTS PER STAFF MEMBER, SPACE PER STUDENT, AND COMPUTER EQUIPMENT PER STUDENT. COMMUNITY-ESTABLISHED LIMITS ARE THE OPERATING BUDGET, CAPITAL BUDGET, AND COMPUTER BUDGET. THE SIMULATOR PROGRAM CAN BE USED TO DETERMINE THE OPTIMUM POLICY TO BE ADOPTED IN TERMS OF THE FOREGOING PARAMETERS AND LIMITS. THE FORTRAN PROGRAM IS INCLUDED IN THE APPENDIX. (HM)

SOME RESULTS OF A SIMULATION OF AN URBAN SCHOOL DISTRICT

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March 30, 1967

This research is supported by the School District of Philadelphia utilizing funds made available under Title III of the Elementary and Secondary Education Act. (This is a report of Phase I of the contract.)

Mr. David Horowitz, Associate Superintendent of Planning and Dr. John Hayman, Director of Research of the School District of Philadelphia have greatly facilitated the development of these models and obtaining the data for them.

Messrs. Martin Stankard and Miguel Szekely have been of great help in all phases of the study.

Report Number: 042467

This paper describes a simulation model of an urban school district. The results of operating the simulation under various conditions is presented. The results are forecasts of financial requirements and operating statistics.

It is demonstrated that such simulations are feasible and concluded that they are useful.

Based on this model estimates are made of the cost of operating the particular school district under various sets of policy.

MODEL AND RESULTS

The School District of Philadelphia has been modelled by a computer simulation. The purpose of this simulation is to:

- demonstrate the feasability of simulating an urban school district.
- provide some preliminary guidelines as to the effect of major policy changes on the District's financial outflow and operating statistics.

Both objectives have been accomplished.

The model represents the District as a single aggregated enterprise. The characteristics of the model are these:

- time proceeds on a year-by-year basis; the model provides a "snapshot" of the situation at the end of each year.
- two areas are represented, the inner core and the outer, suburban-like perimeter.
- students are considered a homogeneous population except for the area they are in.
- staff is divided into two groups, paraprofessionals and all others (the latter including teachers, supervisors and management).
- space is represented by the square-feet available and is procured in amounts equal to schools; with appropriate lead times and costs.
- all other services (including non-professionals) and materials

are calculated as "overhead" items on a per student or per square-foot basis.

- all cost factors have appropriate inflation factors associated with them (ranging from 2.5 % to 4 % per year).

The model computes each year's results (starting from the situation at the end of the previous year) according to the procedure outlined in Figure 1.

This model includes several policy variables; factors which can be set by management. The purpose of a model is to explore the consequences of changing these policies. The key policy represented in this model are:

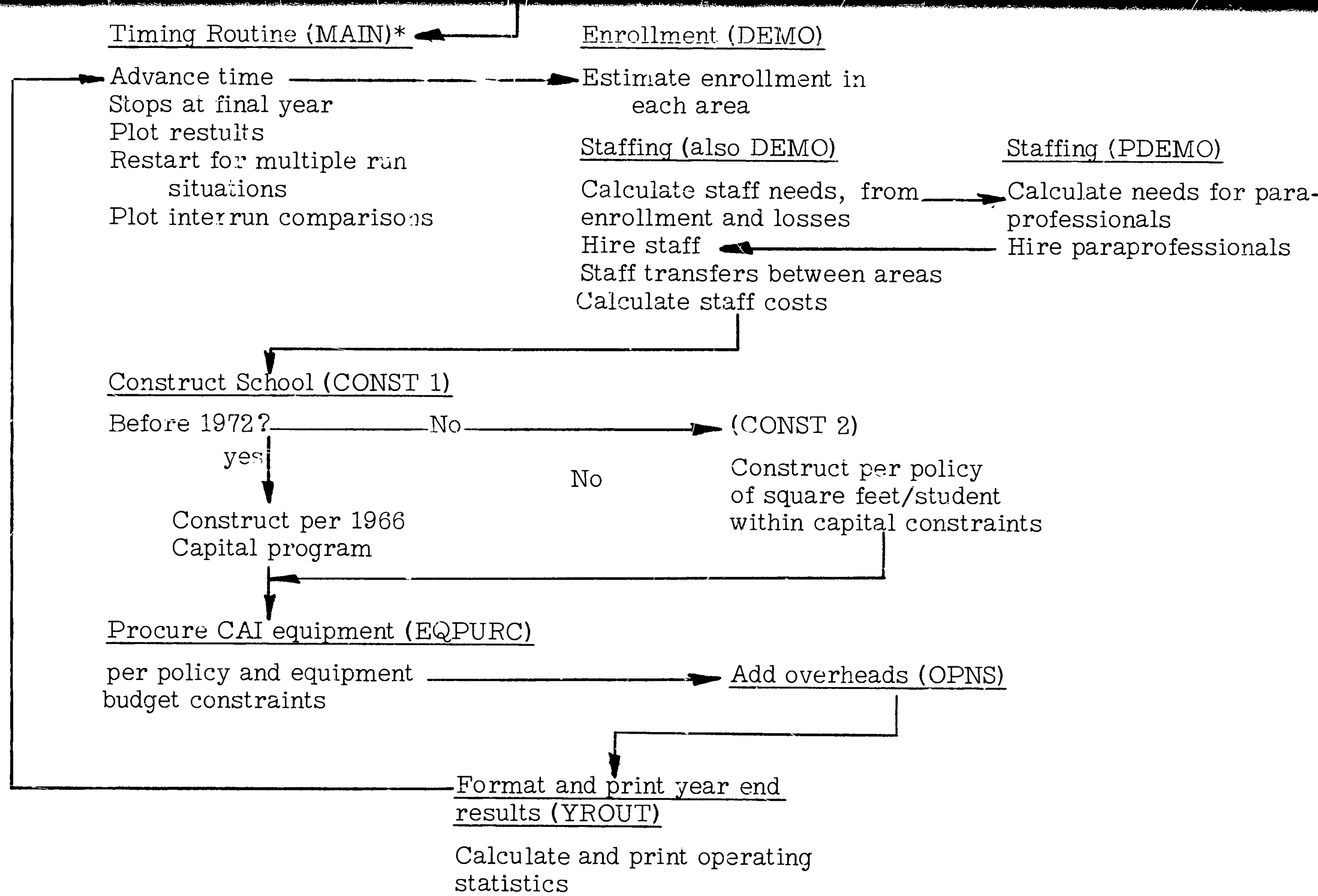
- students per staff (excluding paraprofessionals)
- space per student
- computer-assisted-instruction (CAI) equipment per student
- students per paraprofessional
- paraprofessional per staff
- staff salaries
- paraprofessional staff salaries

These are represented as averages over each of the two areas.

The model also includes three policies set by the community:

- operating budget limit (equivalent to dollars per student).
- capital budget limit.
- computer (CAI) equipment budget limit.

The studies made to date using the model vary these policies in order to determine the effect on the operation in the District. Not all



OVERALL FLOW CHART

Figure 1

* Subroutine names in capitals

of the policies have been varied in the many possible, or even most of the interesting, combinations. In all studies so far no limit has been set on operating budget and no operating budget allocation procedure is included. The policies actually varied are implied in the description of results below.

Figure 2 shows a typical result at the end of a year. A summary of the operating costs is given, followed by operating statistics and then the capital costs. Other data is available in the computer which is not printed out, such as the proportion of staff assigned to supervising para-professionals.

Figure 3 is a typical summary plot provided by the computer simulation for presentation. Below this data has been transcribed onto special graphs for ease of analysis.

The results can be best understood by reference to Figures 4 through 8.

Figure 4 shows two assumptions used about enrollment. The lower or normal is one of the forecasts now used by the Facilities Planning Department of the District. The upper or pessimistic curve represents a situation which might result if a major shift occured from private to public schools. Since there are about 500,000 school age children in the city, the pessimistic curve assumes most of them will be in the public schools by 1980.

Figure 5 shows the total operating costs over time that result from various combinations of policies. The A curve is a forecast of

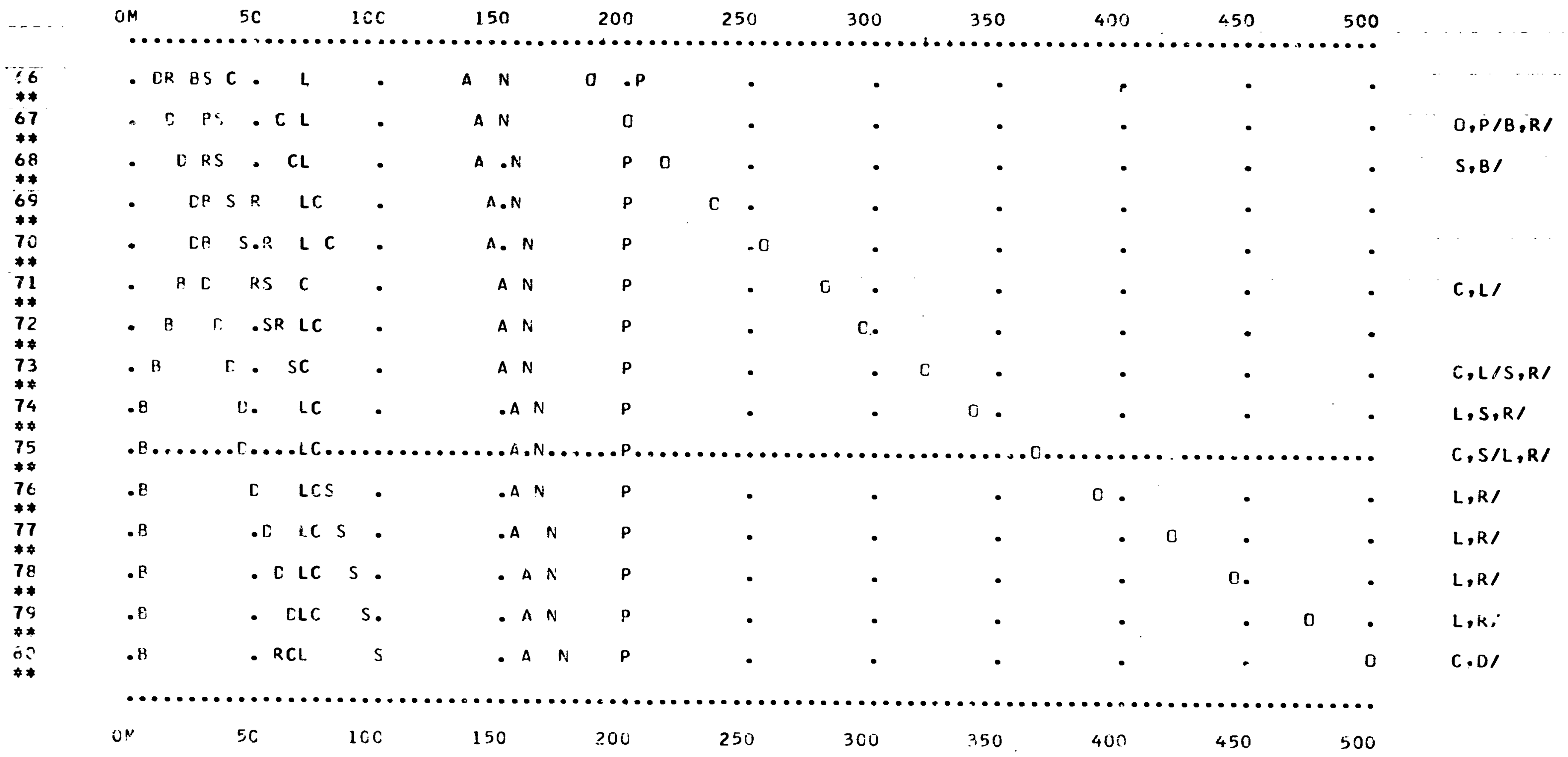
```
CPERATING COSTS FCR YEAR 1970

STAFF SALARIES                                   287622212.

PROF. STAFF $                          178382032.
PARAPRCF. STAFF $                      109240182.

TCTAL CVERHEAD                                    91158890.
     CVERHEAC DETAIL
     PLANT OPNS ANC MAINT.              31120684.
     ECUIPMENT                           1778224.
     BCCKS AND ED. MTL.                  7560098.
     TRANSPCRTATION                      5545346.
     HEALTH SERVICE                      4625354.
     REP. ANC MAINT. OF EC.               723304.
     CEBT SERVICE                       27051345.
     CCNTRACT SERVICE                   12748539.
TCTAL CCSTS                                      378781100.



CPERATING STATISTICS

    293000. STUCENTS IN  12555499. SQ. FT.
FCR AN AVERAGE CF     43. SQ. FT. PER STUDENT

NC. STUCENTS AREA 1 121CCC.  AREA 2 172000.  TOTAL 29300C.
STAFF        AREA 1   6914.  AREA 2   9206.  TCTAL  1612C.

PCSITICNS CPEN   1643.

STUC./STAFF  AREA 1    17.5  AREA 2    18.7  TOTAL    18.2



TCTAL PARA. STAFF      19412.          PARA/STU              15.1

PARA. BY AREA          8203.6   11208.1        PARA/STU BY AREA              14.7    15.3

CAPITAL EXPENCITURES FCR 197C

ACCITICNS,IMPRCVEMENTS,REPAIRS          27768248.
NEW CCNSTRUCTICN                        52591879.
TCTAL CAPITAL CUTLAY                              80360125.

CAPITAL EQUIPMENT                                        0.



YEAR 7C COMPLETEC
```

Figure 2.

Typical Printout: This is the printout for 1970 in the run that includes hiring and use of paraprofessionals. No CAI equipments is procured in this run.

PARA means paraprofessional
STU means student

GRAPH FOR ABOVE DATA



O=OP COSTS C=CAP COSTS N=STAFF NEEDED A=STAFF AVAILABLE L=CAPITAL LIMIT

D=DEBT SERVICE P=ACTUAL STU/STAFF S=SPACE/STU B=$ NEW CONST R= $ ADDITIONS

Figure 3.

A plot of data from the run that forecasts costs and operating statistics if no substantial change in policies is undertaken. (Symbols at right show superimposed values.)

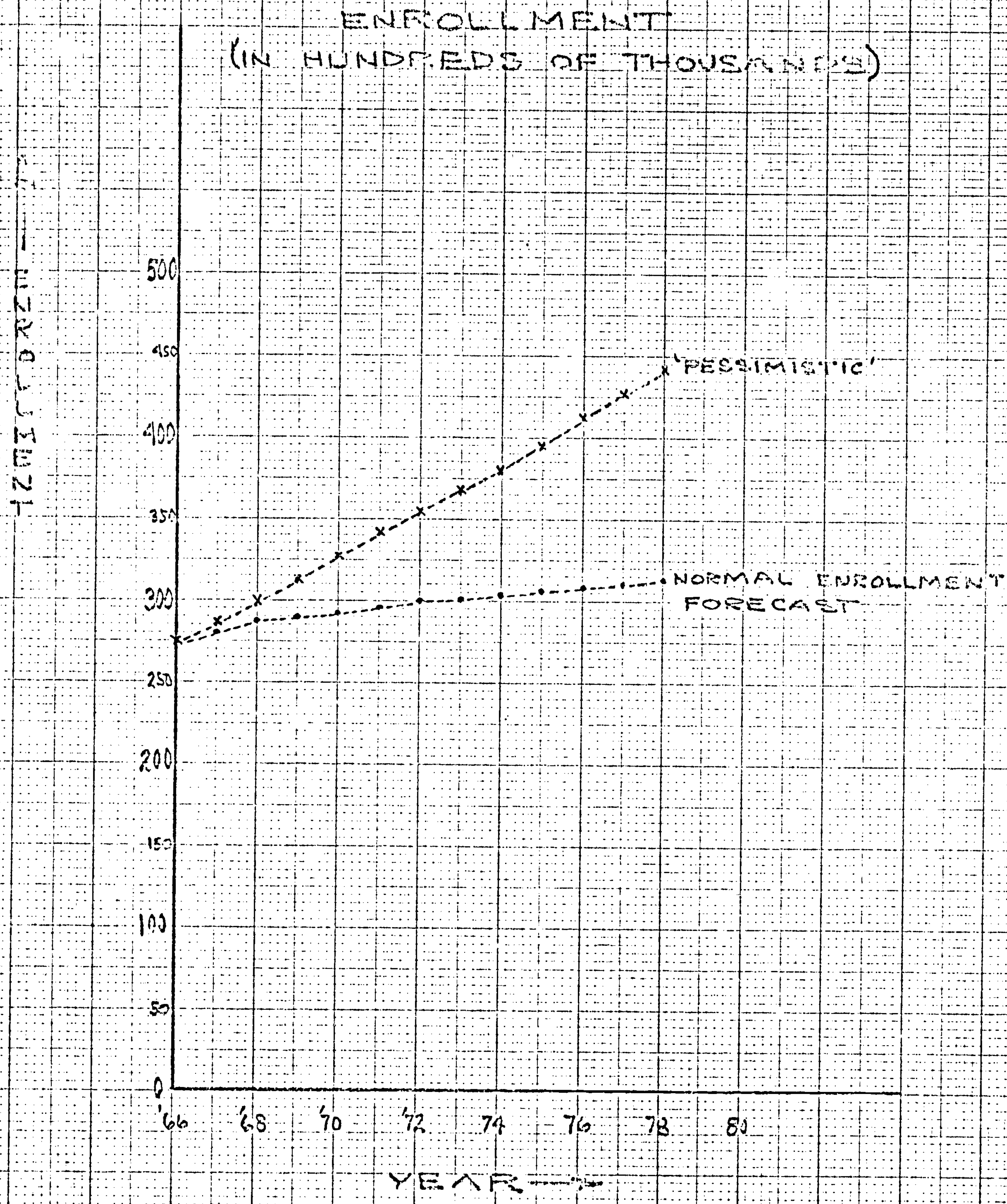


FIGURE 4

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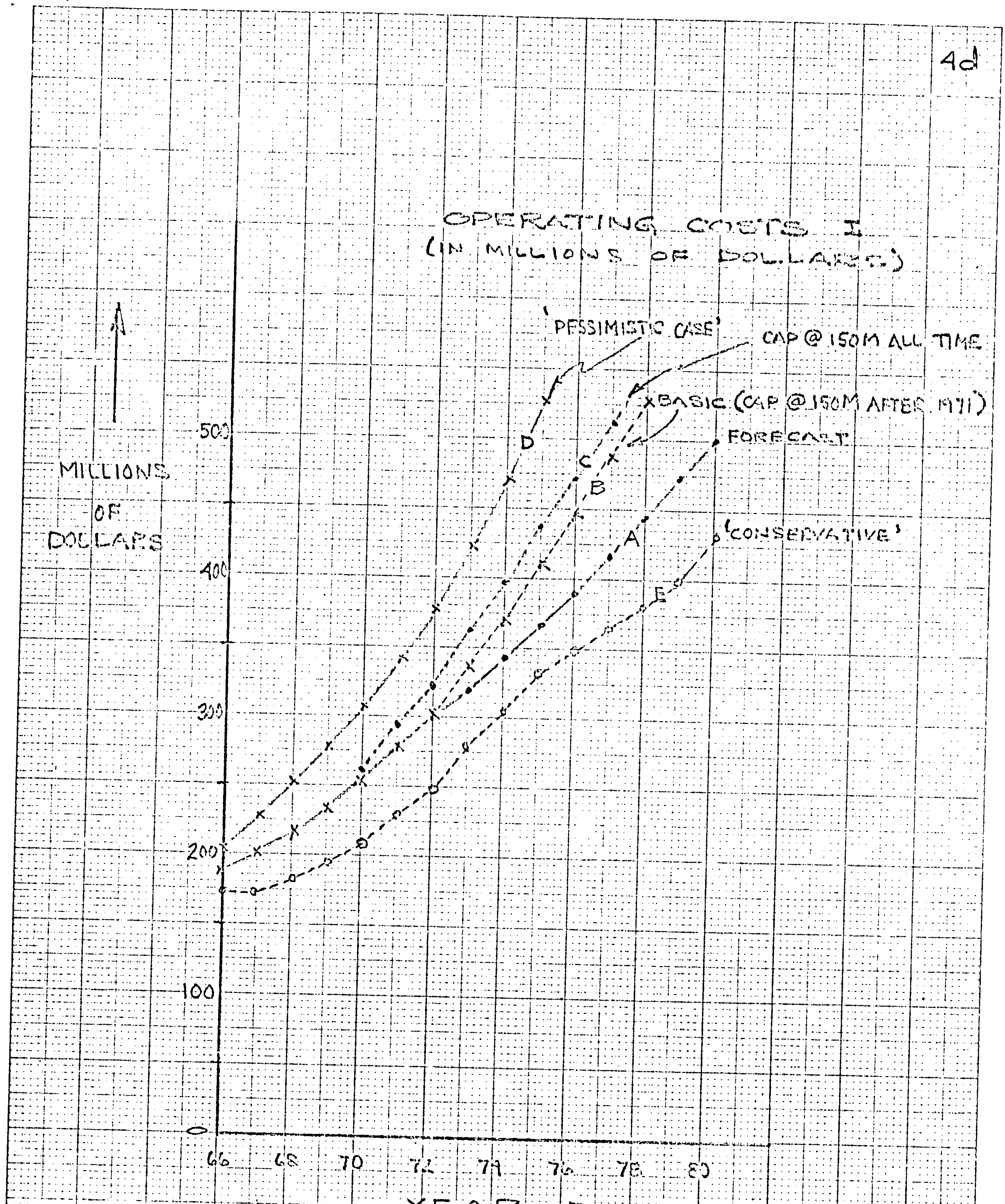

FIGURE 5

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costs if no substantial policy changes are made. In this situation the student/staff policy is 18.5, which is the ratio actually attained in 1965. The space policy is 150 sq.ft. per student. No paraprofessionals nor CAI computer equipment is procured. The capital budget is limited to approximately $70 million per year and the normal enrollment curve is used.

This A forecast is slightly lower than a five-year forecast recently madey by the Finance Division of the School District. The difference is a result of two factors: The model assumes a higher student/staff ratio and also takes into account the fact that not all staff requires can be hired.

The B forecast is the same as A except that the capital budget limit is $150 million after 1971. The increased costs after 1971 reflect the effect of the added space on the operating costs especially debt service. The C curve is the operating costs for a situation in which the capital budget is $150 million throughout the period (although this does not have much effect until 1970 due to construction lead times). Curve D is the predicted operating costs under a combination of pessimistic events and generous policies. It represents a "worst case." Here, the enrollment increases according to the pessimistic curve in Figure 4. The desired student/staff ratio is 15 and the space per student is 175 sq. ft. (Lower student/staff ratio implies more teachers and therefore, higher costs.)

Curve E is correspondingly conservative; enrollment is assumed to be lower than the normal curve and a student/staff ratio of 25 and a space-student ratio of 125 are considered satisfactory. This curve represents the lowest costs the District could expect to incur.

Figure 6 demonstrates operating costs under other more dramatic conditions. Curve B is the same as the basic curve - B - in Figure 5; it is included here for reference.

Curve A in Figure 6 represents the School District under a policy which procures CAI systems and utilizes fewer teachers. The budget for equipment is $30 million per year. Under this limit, computer equipment is acquired until 1973 when there is enough for the entire system. Curve F at the bottom of Figure 6 shows the percentage of students using CAI at each point in time. The student/staff ratio policy for parts of the system with CAI is 35. (However, since staff is not relased, but is reduced though attrition this ratio is not attained until 1980.) Note that use of CAI appears to reduce operating costs. Its effect on the education of the students has yet to be determined. Several other studies have been made with equipment budget limits of $10 million and student/staff ratio of 25. No unexpected forecasts resulted.

Curve C demonstrates an effort to test the effect of an assumption on the results. The model for the runs discussed above assumes that only a fraction (58 %) of the staff needed in any year is actually hired. This represents the supply-demand effects in the market for teachers, i.e., it represents the fact that there are not enough teachers available, and the fact the recruiting facilities are limited. Curve C is the same as curve B except that it assumed that all staff needed can be hired up to a limit of 2000 per year. More staff is hired under this assumption, hence

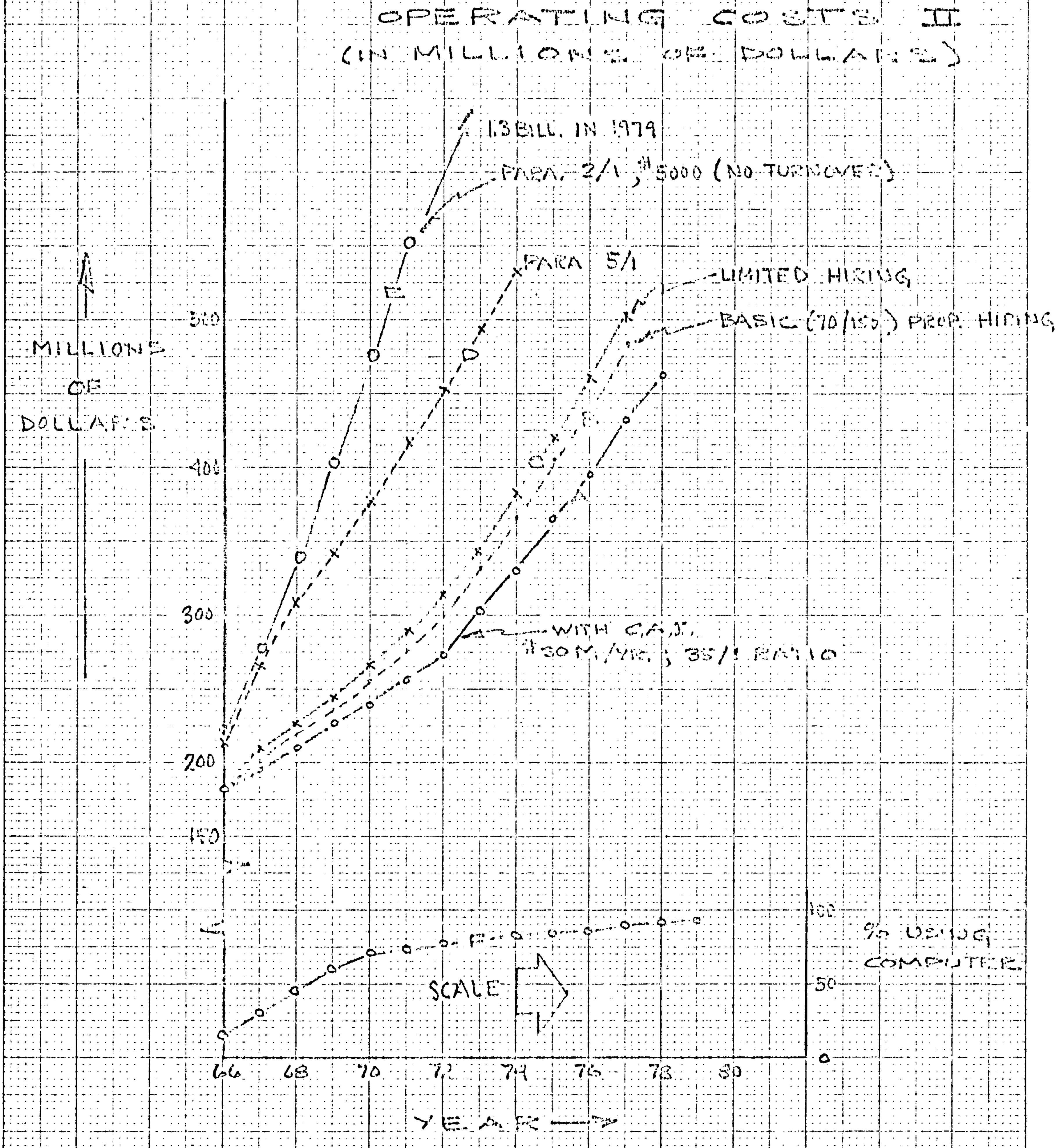

FIGURE 6

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costs are higher. Further study is under way to choose the most valid assumption about staff hiring.

Curve D represents the District operating under a policy in which paraprofessionals (non-certified assistants) are hired to increase the intensity of the educational effort. The goal is to hire enough assistants to obtain a student/paraprofessional ratio of 5. However, limitations on hiring and the turnover of paraprofessional personnel prevent this ratio from going lower than 13.5. The average salary of a paraprofessional is assumed to be \$5000 in 1966 and inflates at 3 % per year. Under this condition the total staff-student ratio in 1975 is estimated to be 7.6. Note that this policy is quite expensive.

Figure 7 shows the staff situation for the basic situation; curve B in figure 5. Note the predicted continued staff shortage.

Figure 8 illustrates the effect of varying capital budgets. The upper curves show the square feet per student realized under three different rates of expenditure. Increasing the budget limit in 1971 to \$150 million does help attain the desired space ratio sooner.

This study is continuing in several directions:

- A model of the sources of funds is being developed so that operating cost limits can be set.
- An attempt is being made to model educational effectiveness (in terms of changes in achievement levels on basic tests)
- A submodel will be incorporated to represent management allocation of operating funds between factors (staff, materials, paraprofessionals).

STUDENT / STAFF RATIO AND STAFF SHORTAGE

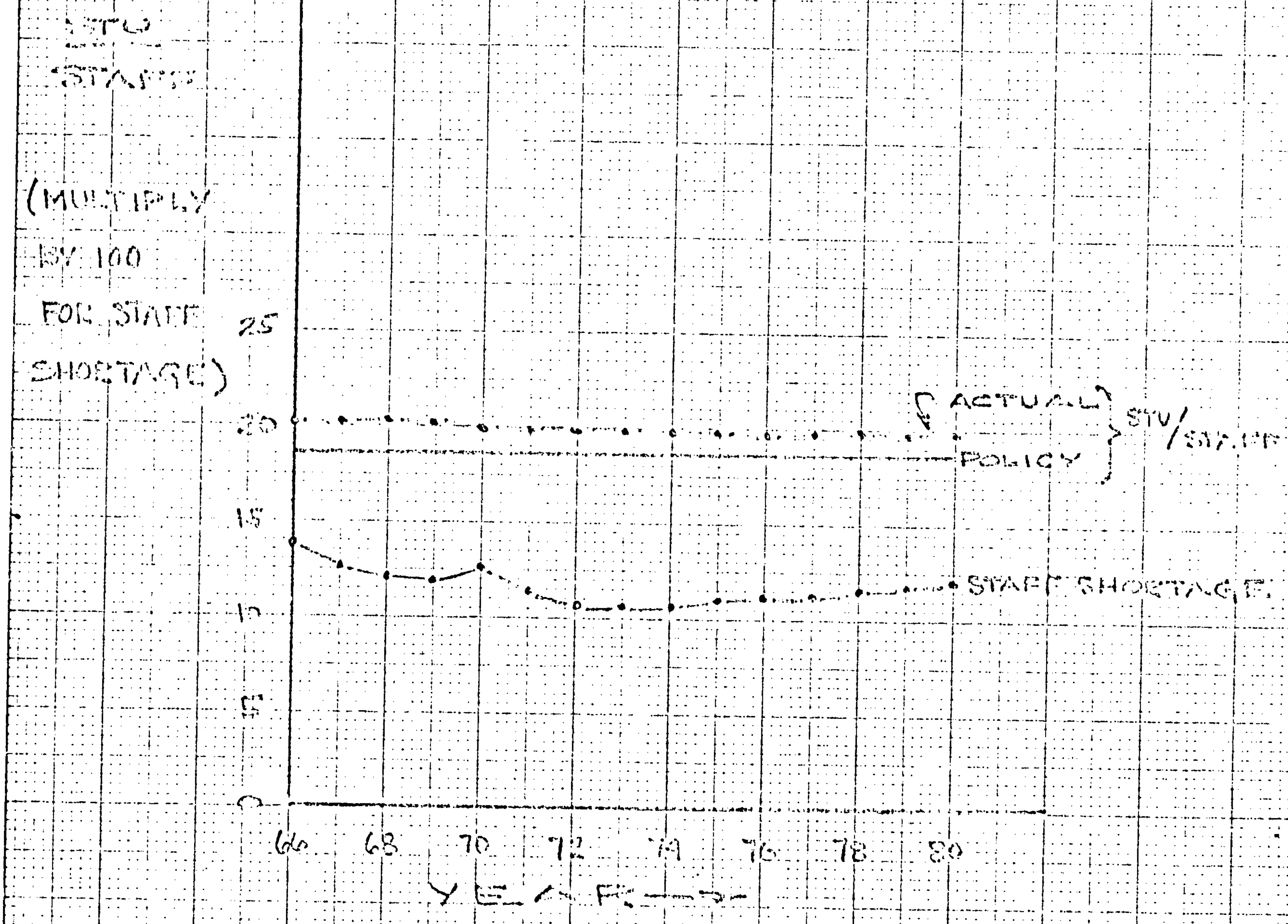

FIGURE 7

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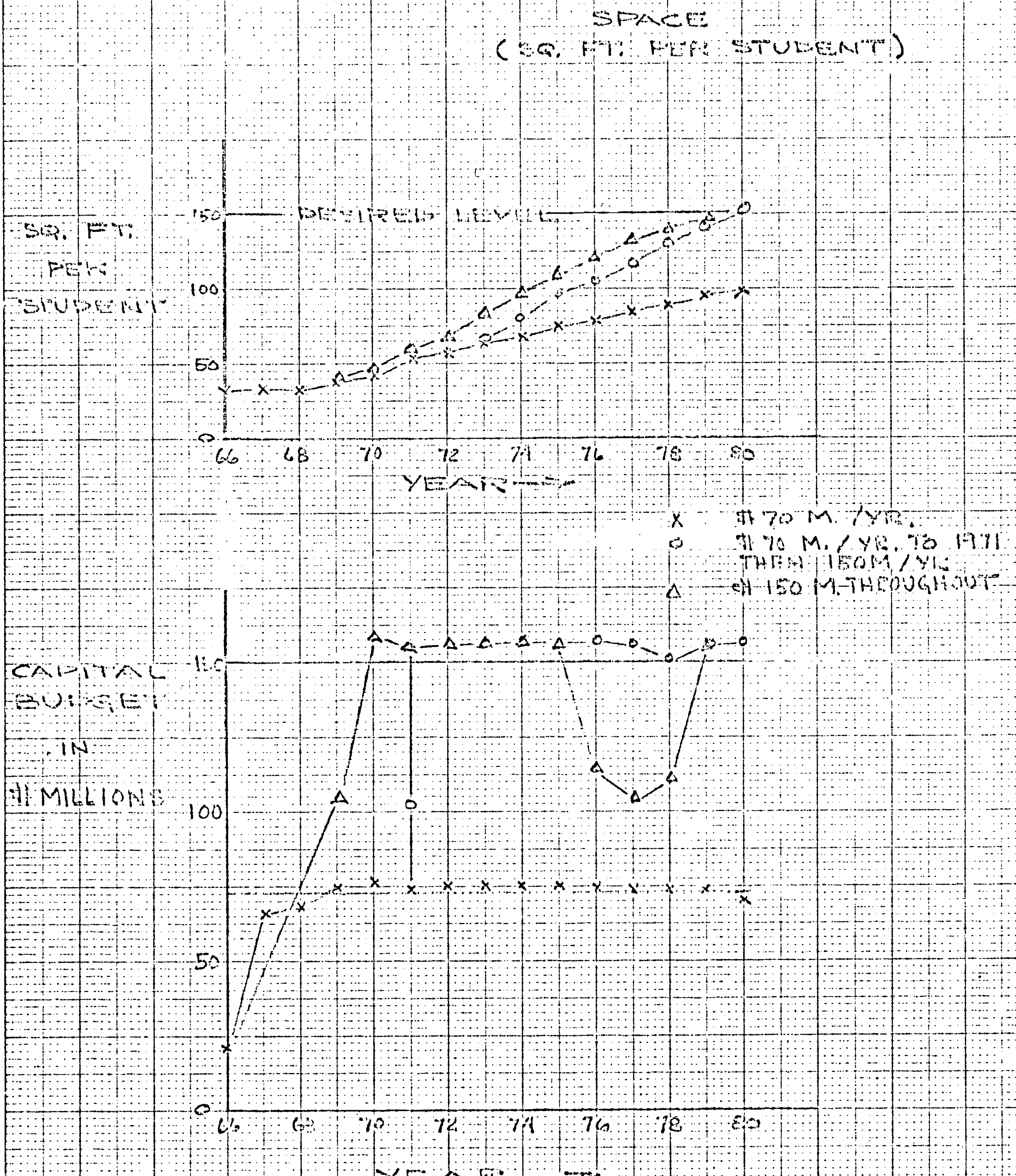

FIGURE 8

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When these additions are completed, a study will be made to determine the settings of the policy factors which give the most effective operation. Another study will try to identify the method of planning which permits the schools to adapt most effectively to changes in the environment (e.g., in student enrollment and student characteristics).

In addition to continuing work on this model, a new, more detailed model is under development. This will contain explicit representations of areas within the district, of student characteristics and achievement and of educational programs.

Planning is under way to perform studies in the School District of Philadelphia to validate this and future models.

TECHNICAL DISCUSSION

The Problem

School districts must allocate limited resources to specific activities (as must any goal-oriented enterprise). There are difficulties in making an optimum allocation in a school district, and especially in a large urban school district. These difficulties ensue partly from some inflexibilities in resources, they stem to a larger extent from non-additive interactions between activities but perhaps, mostly they stem from a lack of well-defined value or objective functions.

The key limited resources of a school district are money, professional monpower and space. In general, availability of materials and non-professional manpower is not a significant limitation. All three of the key limited resources have inflexibilities which restrict their deployment. These inflexibilities are similar to those found in industry but more severe. Manpower is less mobile, even within a city. Many female teachers insist on working near their homes. State laws and sometimes union agreements limit the extent to which teachers can be transferred. Teachers with skills are (at least are perceived to be) non-interchangeable.

Space is also inflexible to some extent. Gyms cannot be used for classrooms (in most designs), but music rooms can be (and often are under todays present crowded conditions) used for other classes.

Completely unlike industrial financing, school districts have a percentage of their funds precommitted. Some funds are available, for example, to be used only for reading, only for preschool, only for the handicapped or the gifted, only for the construction of classrooms, etc. This precommitment of funds restricts school district management (as was the intention of the administrators of the source of the funds) and complicates the allocation process.

The objective of the education system is to change the present and future behavior (or potential behavior) of the students being educated. The essence of education is the communication process - educating may be thought of as: the communication of information about alternative classes of behavior, the communication of instruction or technical competence in performing certain functions, and in transmitting values for outcomes of various ways of behaving. The activities selected by schools to achieve the objective depend upon the ways in which the schools feel that the informing, instructing, and motivating tasks of education may be efficiently performed.

Only part of the education processes is performed by the schools. A student interacts with many parts of his environment - his mother, father, siblings, peers, communications media, teachers, classmates, and curriculum material. Only the last three are supplied by schools, but the fact that significant education (communication) goes on in the home environment implies that schools must become increasingly involved there through parent groups and community activities.

A basic activity of the school is the creation of an environment in which specially trained adults (or a machine - e.g., film projector or a computer) can communicate specific facts, values, or problems to a student within a group of students. The creation of such an environment, periodically, will be called an educational program, or simply a program. Because children have a limited attention span and because there is a wide variety of messages to communicate and experience to present, a student participates in several programs, even in one day. The variety of programs is further increased in the urban school district because of the wide range of ages, capability levels of achievement, desires, and environments reflected in the large student pobpulation.

This variety causes many administrative problems in the area of organization, personnel selections, curriculum design, and resource allocation. This study focuses on the last of these.

In attempting to solve any of these problems, the educational administrator is trying to obtain the best educational performance possible. There are, however, no agreed-upon measures of educational performance. This lack of a way of evaluating the performance of a teacher, a school, a principal or a district makes the job of administration nearly impossible, inviting petty politics and "suboptimization". The research, of which this study is a part, is attempting to design such measures.

The research is proceeding in phases. The first, reported here involves a model which is limited to the prediction of operating characteristics and financial implications of alternative resource allocations. The next phase will develop measures and techniques for evaluating the educational consequences of resource allocation.

This effort is research; its overall objective is a better understanding of urban school complexes. The models developed may also be valuable to practicing administrators for use in setting priorities, selecting programs and justifying expanded budgets.

Approach

A basic theme of this research is that we must develop precise models of the educational system if we are to make better allocation (and other) decisions. Therefore the principal aims of the study are:

- to design a precise model of an urban educational system expressed as a computer simulation program and
- to explore the consequences of some basic alternative allocations.

The present model is aggregate and therefore exploratory. A more detailed model is under development. Some interesting results have been obtained even with the aggregate representation of the School District; these are reported herein.

Two earlier reports [References 1, 2] have described the overall research and the early development of this model.

Derivation of the Model

The simulation model represents the School District of Philadelphia in sufficient detail to forecast operating and capital costs by major categories.

The first design decision was the selection of a level of aggregation. One could conceive of building a model which represents every teacher - child interaction and every administrative interaction on, say, a minute by minute basis. This may be the level of detail required in the ultimate model, but is far too complex for the initial effort. (Although in designing the ultimate model we would hope that we have sufficient understanding to abstract many of the detailed processes.) An intermediate model would represent each educational program and its operation over the school year. In an intermediate model, some of the variables that might be represented are:

- geographic areas (schools or clusters of schools),
- detail in classifying teachers (by subject, skill, experience),
- details of educational programs,
- detail in classifying students (by age, achievement, socio-economic factors, IQ),
- recognition of different uses of space,
- various classes of equipments.

Even this level of detail can lead to a very large simulation. (Work on a model at this level is proceeding.) To demonstrate feasibility, a very aggregate model was chosen as a first goal. In this model the following distinctions are made:

- Time proceeds on a year-by-year basis.
- The entire district is divided into two areas (corresponding approximately with areas of disadvantaged and of normal conditions).
- No details of student characteristics are represented (except the area in which they live).

- Staff is distinguished only as to whether it is professional, which includes teachers and administrators, or paraprofessional, which represents non-certified teaching assistants and volunteers. (Non-professional staffing is subsumed in overhead factors.)
- Some detail is given in representation of space. The level of the school (elementary, junior or middle, and senior high) and five different space uses are distinguished.
- Equipment for computer-assisted instruction is separated from all other supporting equipment.
- No categories are recognized within educational materials.
- There is no separate representation of educational programs; changes in programs are assumed to be represented by their effect on aggregate operating characteristics (e.g., staff/student).

The choice of this level of detail was the result of an interactive process which estimated the probable computer program implications of including more detail and, on the other hand, examined the kind of questions one would like to explore with the model when available.

Major Subsystems

A major step in model building is the identification and representation of major subsystems of the phenomena being studied. This is a creative step, for which there are few rules. In any particular case, however, the functional subsystems are usually fairly evident. The discussion below will make clear the processes included within this model.

A school system's activities are driven by the student enrollment. The first subsystem, therefore, is a demographic process which, in its full form, would represent birth, growth and movements of children in families throughout the district. Separate census and demographic studies have been made in the Philadelphia district. These produced forecasts of enrollment in (approximately) the two areas represented, at five year intervals from 1965 to 1985. The current model starts with these forecasts and does not explicitly represent the demographic process.

A second subsystem includes staffing procedures; hiring, transfers between areas, resignations.

A third subsystem represents the provision of space for teaching. Specifically, it includes the construction of new schools, additions to schools and the demolition of substandard structures.

A fourth subsystem procures computer equipment for computer-assisted instruction (CAI). The schools are just beginning to use such equipment and it is included in order to be able to study the future financial effects of CAI.

Next, one would want to represent the actual process of education. The output of this process would be estimates of the achievement of students as a result of the programs provided. This submodel is under development, but not yet included. Thus the model now represents only the financial and people flows.

A school system provides many supporting services. In the model these are represented by an overall "overhead" subsystem which estimates costs for these services. Included services are: books and materials procurement, health services, minor equipment procurement, equipment repair and maintenance, miscellaneous consulting and contracted services (e.g., caferterias), transportation, and debt service on bonds for construction (net of subsidy).

A school district interacts with the remainder of the community in many ways, not represented here. In particular, the generation and input of financial resources through taxes, subsidies and grants is not represented as a process. This system boundary is represented by limits on funding available for capital programs and is ignored for the operating budget. In other words, the system operates as if it could obtain all the operating funds it needs. This unrealistic assumption is being eliminated as the model is refined.

Description of Principal Calculations

Figure 1 is a summary flow chart for this model. In this section the basic algorithms for each process will be presented. Details are given in Appendix 1.

Enrollment

Enrollment forecasts are available for enrollment in the Philadelphia Schools at 5 year intervals from 1965 through 1985. Enrollment is estimated between these points by linear interpolation and by a linear extrapolation of the 1980-1985 forecasts for years beyond 1985. Enrollment is separately estimated for each of the two geographic areas.

Hiring

Next the hiring process is represented. A complete representation would include a submodel of the market - the supply, demand and resulting salary levels - for teachers. The teacher supply process is complex and the development of this submodel would lead away from the main interest of this study (although it has to be done eventually). But we do have to represent the market from the viewpoint of the school district, to account for the fact that it cannot hire all the teacher it needs. This has been represented, approximately, by equations which produce hiring results of the form shown in Figure 9.

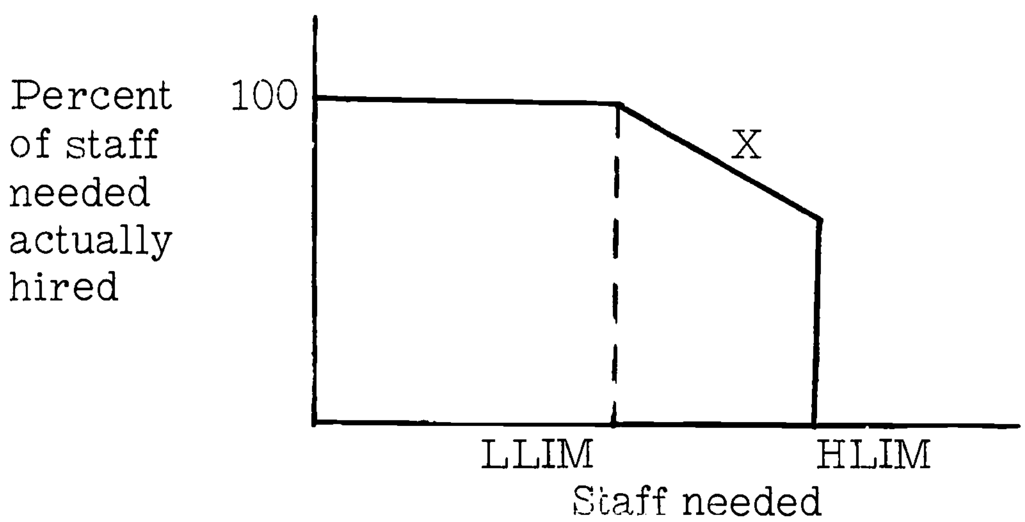


Figure 9.

For needs less than LLIM all needed are hired. In the range from LLIM (often set = 0 in actual runs) to HLIM a proportion, X, of those sought are actually recruited. In any one, year, however no more that same maximum number of appointments, HLIM, can be made. The latter represents the fact that the recruiting and personnel processing capability of the school administration is limited.

The model takes into account transfers between the two areas of staff. Transfer rate between two areas is based on the experience in the 1963 through 1966 period. This however, represents a very small fraction of the total staff required.

Staff costs are calculated by multiplying the available staff by the average salary (including fringe benefits). A cost can be assigned for each person hired (although in the current model this charge was set at 0 and in any case it would be a small fraction of the total operating budget).

An analogous set of relationships is provided for staffing for para-professionals; non-certified assistants and "volunteers."

Space

Space is provided by the construction of schools. (Rentals are not considered in the present model.) This construction is represented by two separate processes; the first applies from 1966 through 1971 and the second thereafter. The first constructs schools according the existing (1966) six year capital budget and plan. After 1971, space is added in relation to a space-per-student goal constrained by a capital expenditure limit.

The first construction routine explicitly represents the level of school and type of space.

In the post -71 routine; schools are added each year in the sequence: Elementary, Middle, High. Each school adds a number of square feet (by categories of use) and incurs costs which are scheduled over 3 to 5 years. Schools are added until either (a) there is enough space (per policy)in all of the years being scheduled (five) or (b) a capital limit for a year is exceeded. The space needed is derived by multiplying the space-per-student goal by the estimated number of students for the year under consideration.

CAI Equipment

CAI equipment is added in a manner analogous to space construction, but without considering lead time or various types of equipment. The equipment needed in a year is estimated by multiplying the computer cost per student by the number of students and subtracting the equipment already available. The eqipment purchased, however, cannot exceed a specified limit.

In addition the desired staff/student ratio is adjusted as computing equipment is procured. For example, without computer a ratio of 15/1 might be desired (recall this is total staff not just teachers). For that portion of the student body that has CAI available the ratio might be 25/1.

Overheads

The various overhead factors are calculated as a function of the most appropriate operating variable. The overhead cost ratios are derived from data available for the 1963 through 1966 period.

The specific overheads are as follows:

- Health Services which are a function of the number of students enrolled.
- Transportation Services also a function of the total enrollment.

- Contract Services which include maintenance and minor repairs to buildings as well as other miscellaneous services; this cost is a linear function of both the total enrollment and the number of square feet of space in the system.
- Books and educational materials which are a function of total enrollment.
- Equipment costs (this is equipment other than that required by CAI) which is a function of total enrollment.
- Repair and maintenance of equipment which is a function of total dollars worth of equipment owned by the system.
- Plant operations and maintenance which is related to the total square feet of space in the system.

  Debt service is related to the accumulated construction costs for new buildings over the past years; appropriately decreasing as the debt is paid.

Appendix 1 relates these various calculations tc specific part of the computer program.

In addition to these basic computations there are input/output routines:

- to format a report of operating and capital budgets and operating statistics,
- to plot key variable after each run and a few key variables in a comparison of several runs.

Experimental Plan

There are 11 key controllable or policy variables:

- students per staff,
- space per student,
- computer-assisted-instruction (CAI) equipment ($) per student,
- students per paraprofessional,
- paraprofessional per staff,
- staff salaries,
- paraprofessional staff salaries,
- materials ($) per student,
- operating budget limit (or dollars per student)
- capital budget limit,
- computer (CAI) equipment budget limit.

The first eight of these are controllable by school administration. The last three are controllable by the community. The studies to date have not varied (or experimented with) all of these. There are also several variables representing the District's environment which we wished to manipulate in order to determine their effect on the budget. Among these are the following:

- population enrollment growth; which we vary to determine the effect of mis-estimating enrollment forecasts.
- the effect of the assumption that the number of staff hired is proportional to, and less than, the staff needed.

There are, of course, many other variables whose effect can be explored with the simulation. However, the runs made during the initial test period were limited to some of these variables. The actual experimental plan is presented in Table 1. The first run, which might be called the basic run, was operated under the following conditions.

- student/staff policy = 18.5 (This was the policy or the actual ratio in effect in 1965)
- Student/space policy = 150 sq. ft. per student. (This is a very generous amount of space, considered desirable by some school facility planning authorities, 60 sq. ft. per student properly designed, may be adequate in an urban district, and additional runs will be made on this basis.)
- Student-paraprofessional ratio. In the basic run no paraprofessionals were hired.

CAI policy. In the basic run it was assumed that no computing facilities were used for teaching purposes.

In the basic run the capital expenditures were limited to 70 million dollars per year which is approximately the limit of it now in effect. Since no CAI was utilized, no budget limit was set for it.

It was assumed that the staff actually hired was 58 % of the new staff needed in any one year. This percentage was the actual experience over the years 1960 through 1965.

The enrollment was assumed to be that established by the forecasts derived by a separate study (see Figure 4).

RUN
(Note 4)

Policy or Parameter	1 Fore-cast	2 Basic	3 Pess-imistic	4 Conser-vative	5 Mixed	6 Hi. Capital	7 Limited Hiring	8 CAI	9 CAI	10 CAI	11 CAI	12 Para prof.
Stu./staff policy		18.5	15.	25.	18.5/15			25	25	35	35	
Space/stu. policy (1)		150	175	125								
Stu./para policy		No Para.										5
$CAI/stu. policy		No CAI						700	700	700	700	
Capital limits (2)	70	70/150				150						
CAI Budget limit (2)		-						10	30	30	10	
Hiring (3) assumption		Pro-portional					Fixed Limit					
Enrollment growth		Normal	+3% per yr.	-3%								

(1) square feet/stu.
(2) millions dollars
(3) see text
(4) entries show changes from run 2.

Experimental Plan

TABLE 1.

Run 2 is the same as run 1 except that the capital limit increases to $150 million after 1971. This was taken as the basic run from which all others varied in one or more policy factors.

Run 3 was intended to explore the upper limits of deviations from these policies, but still without such major changes as the extensive use of paraprofessionals or of CAI. The conditions for the second run are shown in Table 1. The student/staff policy is reduced to 15 and the space increased to 175 sq. ft. per student. It was also assumed that the enrollment increases three percent per year (note that this is compunded) faster than the existing forecast. This increase in enrollment would mean that the school system would be teacning most of the elementary and secondary students in the school district area by about 1980 (there is at the present time about 40 % who go to private schools).

Run 4 is a conservative run in which the students per staff is increased and the space decreased and the population assumed to grow more slowly than the forecast.

Run 5 is the same as Run 2 except that the student to staff ratio is assumed to be more favorable (15) in the poverty areas of the city.

Run 6 was an attempt to explore consequences of being able to increase capital expenditures immediately. In this run the capital limit is 150 million per year starting in 1966.

In Run 7 the conditions are the same as in Run 1 except that the following rule is made as to the hiring of personnel: as many teachers or staff as are needed are hired up to a limit of approximately 2000. (The

District has been hiring about 1600 new staff per year in recent years.)

Runs 8 through 11 are runs in which it is assumed that the system buys computers by expending a certain capital budget for computing equipment each year. This budget is $10 million or $30 million per year. It also assumes that a satisfactory student-to-staff ratio in the portion of the school district in which computers are used is 25-to-1 or 35-to-1. The four different runs are made by permuting these two conditions (student/staff ratio and limit of expenditures for computers).

In the CAI runs it is assumed that the capital required per student in attendance for the equipment is $700. This includes terminals and the necessary central computing equipment. It is also assumed that the equipment related (educational software) costs per student are $50 per year.

Run 12 is a run which is like the basic run except that paraprofessionals are hired. The desired ratio of students to paraprofessionals is 5 to 1. These people, being part time workers and not professionals, should have a high turnover ratio. It is therefore assumed that approximately 30 % of the paraprofessionals leave each year. It is assumed that their salary including all fringe benefits is $5000 per year (full time equivalent). This is an extreme case, usually most paraprofessionals are non-paid volunteers.

In the paraprofessional run, it is assumed that 1 additional staff member is needed for every 10 paraprofessionals to provide the necessary supervision, and that an additional amount of space (the same as that set aside for one student) is required for each paraprofessional.

Inflation

Most of the cost factors included in the model are inflated by year at varying rates related to estimates of actual inflation found in the literature. In particular, staff costs are inflated at3 % per year and construction costs at 2.5 % per year.

Conclusions

The principal conclusion from this effort is that it is feasible to model an urban school district. The current model is quite aggregate and represents only very gross policy variables. However, it is clear that (with the proper research manpower) a model can be built which will represent the operation in detail, including representations at specific educational programs and their effect on the system.

The principal conclusions as to school operation from this study to date are:

(1) No matter how the system is operating, the operating costs are going to grow quickly toward $300 million per year by 1970 to 1972. Use of CAI equipment can apparently reduce these costs; however, the educational effects of such a change have yet to be investigated. The reduction from CAI will not limit the need for major increases in operating revenues.

(2) It appears that the present capital limit (about $70 million per year) will permit sufficient construction so that the space will increase to a desirable goal (150 sq. ft. per student), but quite slowly. A doubling of the capital budget would permit the space available to increase toward

reasonable levels (100 sq. ft. per student) in the comprehendable future, say 1975. (Note that this model does not include the possibility of renting space; this possibility will be included in future models).

References

1. Sisson, R.L., Applying Operational Analysis to Urban School Districts, Working Paper, Management Science Center, University of Pennsylvania, 1-6-67

2. Stankard, M., and Sisson, R.L., Operations Research and Improved Planning for An Urban School District, Report, Management Science Center, University of Pennsylvania, 1-16-67

APPENDIX 1

Listing and Explanation of the

Features of the Computer Program

MAIN	(Numbers are ISN in listing)
1 - 24	Set up core area
25 - 35	Read run data
36 - 41	Call subroutines with T = 0 to read initial data
42 - 47	Write headings
50 - 117	Set up parameters for each of four runs (1); is the last run: yes
105	Set Capital budget limit, BC (I), for years 2 to 5 to same as year 1 and years 7 through 40 to year 6 (years after start of run), (limit for years 1 and 6 are inputs).
120	Set T to just year (STARTM)
122 - 132	Call subroutines to perform simulation
133	T = last years (STOPTM)? yes / no
136	T = T+ 1
141 - 151	Plot results of run (2)
153 - 164	Plot inter-run comparison and stop

(1) The number of runs performed in any single computer "job" can be changed, of course.

(2) GRAPH is a service subroutine for plotting.

```
 $IBFTC MAIN
       INTEGER T,STOPTM,STARTM,RO
     1 FORMAT (I6,I3,I2,I2,I1)
     3 FORMAT (1H1, 'SCHOOL DISTRICT OF PHILADELPHIA')
     4 FORMAT(1H0,'PLANNING MODEL - VERSION 1')
     5 FORMAT(1H0,'RUN NUMBER',1X,I3    ,5X,'DATE',3X,3A6)
    21 FORMAT (1H1,50H                                                  )
    22 FORMAT (1H0,50H                                                  )
    23 FORMAT (1H0,50H                                                  )
     6 FORMAT(1H0,'PARAMETERS READ')
     7 FORMAT(1H0,'YEAR',1X,I2,' COMPLETED')
       COMMON/MASTER/T,STARTM,STOPTM,RO,DOLCEQ,EPS,EL,TOOLEQ
       COMMON/CSTUP/IYF(4),STUF(4,2)
       COMMON/XDEMO/X1(2)       ,X3(2),X4(2),X5(2),X6(2),X7(2),X8(2),
      1X9(2),X10(2),X11(2),PINF
       COMMON /CDEMO/ POP,STU(2),STFA(2),STFN(2),CSTF(2)
       COMMON /CONS1/ DOLANN,DTOT(5),DOL,FT2NET     ,BC(40),FSR
       COMMON /COPNS/ TPOM,TEQ,TBKSED,TTA,THLTH,TRMEQ,TDS,TCNSER,TOH
      1,R1EQ,R2EQ
       COMMON/COUT/CO(99,9),CC(99,9),GSN(99),GSA(99),GCC(99),
      1GDS(99),GST(99),GSS(99),GCN(99),GCA(99) ,IR
       COMMON /CGRA/ IGT
       COMMON /CEQ/ FS,XE2(2),XC2(2),X2(2),PERC
       DIMENSION YX(2)
C
C
C      READ MASTER CONTROL PARAMETERS
C
C
       READ(5,1) RDATE,RUNNO,STARTM,STOPTM,RO
C
C
C      READ RUN NAME, DESCRIPTION
       READ(5,310) DATE1,DATE2,DATE3
   310 FORMAT (3A6)
C
C
       READ(5,21)
       READ(5,22)
       READ(5,23)
C
C
C      READ SUBPROGRAM PARAMETERS
C
C
       T=0
       CALL DEMO
       CALL CONST1
       CALL OPNS
C
C
C      WRITE REPORT HEADINGS
C
C
       WRITE(6,3)
```

```
     SOURCE STATEMENT

      WRITE(6,4)
      WRITE (6,21)
      WRITE (6,22)
      WRITE (6,23)
      WRITE (6,6)
C RUN CONTROL
      DO 40 IR=1,6
C SET UP FOR RUNS
      GO TO (300,301,302,303,304),IR
  300 FS=.7
      X2(1)=.054
      X2(2)=.054
      PINF=0.
      FSR=150.
      BC(1)=7.E7
      BC(6)=15.E7
      R1EQ=50.
      R2EQ=50.
      EPS=700.
      EL=10.E6
      IEQSR=1
      XC2(1)=.04
      XC2(2)=.04
      GO TO 110
  301 EL=30.E6
      GO TO 110
  302 EL=10.E6
      XC2(1)=.0286
      XC2(2)=.0286
      GO TO 110
  303 EL=30.E6
      GO TO 110
  304 GO TO 205
  110 TDS=10.E6
      TDOLEQ=12.E6
      DO 120 I=2,5
  120 BC(I)=BC(1)
      DO 130 I=7,40
  130 BC(I)=BC(6)
      WRITE (6,5) IR,DATE1,DATE2,DATE3
      YX(1)=1./X2(1)
      YX(2)=1./X2(2)
      YY=1./XC2(1)
      WRITE (6,140) YX(1),YX(2),PINF,FSR,BC(1),BC(6),R1EQ,R2EQ,EPS,EL
     1,YY
  140 FORMAT (/' STU/STAFF POLICY',2F10.2/' POPULATION INFLATION FACTOR
     1',F10.4/' SPACE POLICY',F10.0/' CAP. BUDGETCONSTRAINT - TO 71',
     2F10.0,'   BEYOND',F10.0/' EQUIP. COST PER STU.',2F7.3,
     3'   CAPITAL EQUIP. PER STU.',F8.0/' CAPITAL EQUIPMENT LIMIT',
     4F10.0/' STU/STAFF ULTIMATE',F10.2)
C  START RUN
       T=STARTM
     8 FORMAT (1H1)
C
C
```

```
007   SISSON SDCAI                         FORTRAN SOURCE LIST MAIN
SN        SOURCE STATEMENT

     C        START SIMULATION
     C
     C
           30 CALL DEMO
              CALL CONST1
              CALL OPNS
              IF (IEOSR.NE.1) GO TO 31
              CALL EQPURC
           31 CALL YROUT
              WRITE (6,7) T
              IF(T.EQ.STOPTM) GO TO 60
              T=T+1
              GO TO 30
     C
     C
     C        END OF RUN OUTPUT
     C
     C
           60 CONTINUE
              CALL GRAPH (1,0.,500000000.,6HGRAPH ,6HFOR AB,6HOVE DA,6HTA     ,
             16H      ,6H      ,6H      ,4H  OM)
              CALL GRAPH (2,4H  50,4H 100,4H 150,4H 200,4H 250,4H 300,
             14H 350,4H 400,4H 450,4H 500)
              DO 100 IGT= STARTM, STOPTM
          100 CALL GRAPH (3,CO(IGT,IR),CC(IGT,IR),GSN(IGT),GSA(IGT),GBC(IGT),
             1GDS(IGT),GST(IGT),GSS(IGT),GCN(IGT),GCA(IGT))
              CALL GRAPH (4,Y,Y,Y,Y,Y,Y,Y,Y,Y,Y)
              WRITE (6,150)
          150 FORMAT('OO=OP. COSTS',T21,'C=CAP. COSTS',T41,'N=STAFF NEEDED',
             1T61,'A=STAFF AVAILABLE',T81,'L=TOTAL CAP. EQ.'/'UR=R+M OF EQ.',
             2T21,'P=ACTUAL STU/STAFF',T41,'S=SPACE/STU.',T61,'B=STU USING COMPU
             3TER',T81,'R=EQ. COST/YR.'/1H1)
           40 CONTINUE
          205 CALL GRAPH (1,0.,500000000.,6HGRAPH ,6HFOR AB,6HOVE DA,6HTA     ,
             16H      ,6H      ,6H      ,4H  OM)
              CALL GRAPH (2,4H  50,4H 100,4H 150,4H 200,4H 250,4H 300,
             14H 350,4H 400,4H 450,4H 500)
              DO 210 IGT= STARTM, STOPTM
          210 CALL GRAPH (3,CO(IGT,1),CC(IGT,1),CO(IGT,2),CC(IGT,2),CO(IGT,3)
             1,CC(IGT,3),CO(IGT,4),CC(IGT,4),3HEND,Y)
              CALL GRAPH (4,Y,Y,Y,Y,Y,Y,Y,Y,Y,Y)
              WRITE (6,200)
          200 FORMAT ('OCOMPARISON OF RUNS'/'OO,C= RUN 1     N,A,= RUN 2
             1     L,D= RUN 3     P,S = RUN 4')
           50 STOP
              END
```

YROUT

1 - 10	Set up core
11	Skip this subroutine if T = O
14 - 101	Print output (See example in Figure 2)
102 - 106	Compute statistics about paraprofessionals
107 - 116	Print remaining data
117 - 132	Save this year's values of key variables for plotting routine.

```
$IBFTC YROUT
      SUBROUTINE YROUT
C
C
C     YEAR END OUTPUT
C
C
      INTEGER  T,STARTM,STOPTM,RO
      COMMON/MASTER/T,STARTM,STOPTM,RO,DOLCEQ,EPS,EL,TDOLEQ
      COMMON /CONO1/ DOLANN,DTOT(5),DOL,FT2NET     ,BC(40),FSR
      COMMON /CDEMO/ POP,STU(2),STFA(2),STFN(2),CSTF(2)
      COMMON /COPNS/ TPOM,TEQ,TBKSED,TTA,THLTH,TRMEQ,TDS,TCNSER,TOH
     1,R1EQ,R2EQ
      COMMON/COUT/CO(99,9),CC(99,9),GSN(99),GSA(99),GBC(99),
     1GDS(99),GST(99),GSS(99),GCN(99),GCA(99) ,IR
      COMMON/CPDM/ CPS,PSTFA(2),WUCP(2)
      IF (T.EQ.0) GO TO 20
C
C
C     WRITE OPERATING COSTS
C
C
      WRITE (6,1) T
    1 FORMAT (1H1,'OPERATING COSTS FOR YEAR 19',I2)
      CSTFT=CSTF(1)+CSTF(2)
      C=CSTFT+CPS
      WRITE (6,2)  C
    2 FORMAT(1H0,'STAFF SALARIES',T50,F10.0)
      WRITE(6,30) CSTFT
   30 FORMAT(1H0,'PROF. STAFF $',T40,F10.0)
      WRITE(6,31) CPS
   31 FORMAT (1H ,'PARAPROF. STAFF $',T40,F10.0/)
      WRITE (6,3) TOH
    3 FORMAT(1X,'TOTAL OVERHEAD',T50,F10.0)
      WRITE (6,4)
    4 FORMAT (6X,'OVERHEAD DETAIL')
      WRITE (6,5) TPOM
    5 FORMAT(6X,'PLANT OPNS AND MAINT.',T40,F10.0)
      WRITE (6,6) TEQ
    6 FORMAT(6X,'EQUIPMENT',T40,F10.0)
      WRITE (6,7) TBKSED
    7 FORMAT (6X,'BOOKS AND ED. MTL.',T40,F10.0)
      WRITE (6,8) TTA
    8 FORMAT (6X,'TRANSPORTATION',T40,F10.0)
      WRITE (6,9) THLTH
    9 FORMAT (6X,'HEALTH SERVICE',T40,F10.0)
      WRITE (6,10) TRMEQ
   10 FORMAT(6X,'REP. AND MAINT. OF EQ.',T40,F10.0)
      WRITE (6,11) TDS
   11 FORMAT(6X,'DEBT SERVICE',T40,F10.0)
      WRITE (6,12) TCNSER
   12 FORMAT(6X,'CONTRACT SERVICE',T40,F10.0)
      CTOT=TOH+C
      WRITE (6,13) CTOT
   13 FORMAT(1X,'TOTAL COSTS',T49,F11.0///)
```

```
C
C
C     WRITE OPERATING STATISTICS
C
C
      WRITE (6,131)
  131 FORMAT (1HO, 'OPERATING STATISTICS')
      STUT=STU(1)+STU(2)
      FT2AVE=FT2NET/STUT
      WRITE (6,14) STUT,FT2NET,FT2AVE
   14 FORMAT(1HO,F11.0,' STUDENTS IN',F11.0,' SQ. FT.'/
     1' FOR AN AVERAGE CF',F8.0,' SQ. FT. PER STUDENT')
      STFNT=STFN(1)+STFN(2)
      STFAT=STFA(1)+STFA(2)
      POSO=STFNT-STFAT
      TSR1=STU(1)/STFA(1)
      TSR2=STU(2)/STFA(2)
      TSRT=STUT/STFAT
      WRITE (6,15) STU(1),STU(2), STUT
   15 FORMAT (1HO,'NO. STUDENTS AREA 1',F8.0,2X,'AREA 2',F8.0,2X,'TOTAL'
     1,F8.0)
      WRITE (6,16) STFA(1),STFA(2),STFAT,POSO
   16 FORMAT (1X,'STAFF         AREA 1',F8.0,2X,'AREA 2',F8.0,2X,'TOTAL',
     1F8.0,//' POSITIONS OPEN',F8.0)
      IF(POSO .LT. 0.0) WRITE(6,21)
   21 FORMAT(1H ,22X,'NOTE..NEGATIVE POSITIONS OPEN IMPLIES SURPLUS STAF
     1F THIS YEAR')
      WRITE (6,17) TSR1,TSR2,TSRT
   17 FORMAT (  'OSTUD./STAFF  AREA 1',F8.1,2X,'AREA 2',F8.1,2X,'TOTAL',
     1F8.1///)
      TPSTF=PSTFA(1)+PSTFA(2)
      TPSR = POP/TPSTF
      TPSR1= STU(1)/PSTFA(1)
      TPSR2= STU(2)/PSTFA(2)
      WRITE(6,32) TPSTF,TPSR
   32 FORMAT (1HO,'TOTAL PARA. STAFF',T21,F10.0,T41,'PARA/STU',
     1T61,F8.1)
      WRITE(6,33) PSTFA(1),PSTFA(2),TPSR1, TPSR2
   33 FORMAT(1HO,'PARA. BY AREA',T21,2F10.1,T51,'PARA/STU BY AREA',
     1T81,2F8.1)
C
C
C     WRITE CAPITAL COSTS
C
C
      WRITE(6,18) T,DOL,DTCT(1),DCLANN
   18 FORMAT (1HO,'CAPITAL EXPENDITURES FOR 19',I2// ' ADDITIONS,IMPROVE
     1MENTS,REPAIRS',T40,F11.0/1X,'NEW CONSTRUCTION',T40,F11.0/1X,'TOTAL
     3 CAPITAL OUTLAY',T50,F11.0)
      WRITE (6,19) DOLCEQ
   19 FORMAT (1HO,'CAPITAL EQUIPMENT',T50,F11.0///)
C
C
C     STORE DATA FOR GRAPHS
C
```

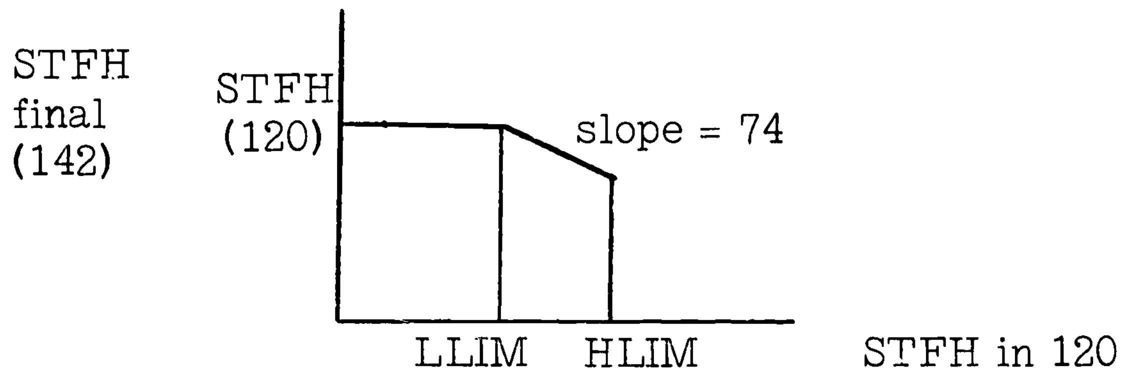
ISN SOURCE STATEMENT

```
C
      CC(T,IR)=CTOT
      CC(T,IR) = CCLANN
      GSN(T)=STFNT*10000.
      GSA(T)=STFAT*10000.
      II1 = T - STARTM + 1
      GBC(T)=TPSTF*10000.
      GDS(T)=TPSR*10.E6
      GST(T)=TSRT*10.E6
      GSS(T)=FT2AVE*1.E6
      GCN(T)=DCL
      GCA(T)=DTOT(1)
   20 RETURN
      END
```

<u>DEMO</u>

1 - 12	Set up core
13	T = O (no → 56)
16 - 55	Read in or set parameters for this subroutine: (This sets up for first run; subsequent runs are set up in MAIN and below.)
56	IIT = years since start of run
57	T > STARTM (yes → 66) (if T = STARTM set up for run)
62 - 63	Set initial staff available (STFA (I)). I = area; 1 or 2.
64	Calculate initial staff needs (STFN(I)). X2 (I) = desired staff/student ratio.
66 - 75	Estimate enrollment IYF (I) = year of forecast I is an index; IYF (1) = 65, IYF (2) = 70, etc. FR = interpolation slope STU (J) = enrollment in area (J) STUF (I, J) = forecast enrollment at year indexed I, for area J.
76 - 77	If T ≤ 85 enrollment is estimated.
101 - 103	Extrapolation to obtain enrollment beyond 1985 (I = 4). RL = extrapolation slope.
105 - 111	Inflate enrollment above forecast if the inflation factor PINF > 0.
113	POP = total enrollment

114 - 136 Calculate staff hired. I = area index
STFI, STFO = staff transferring in an out of areas, (used at 142 - 164).
STFL = staff lost, a fraction X3 of staff available at end of year
STFL = staff hired, calculated per this form:



142 STFN = New staff needs = enrollment times effective staff/student policy XE2. This effective ratio depends on the extent to which CAI is utilized if paraprofessionals are hired there is another factor, SP which adds needs in relation to staff/parastaff requirements for supervision.

143 - 163 Accounts for transfer between areas at a rate X5.

164 - 167 Computer staff cost:
X10 = salary inflation factor
X6 = average salary
X11 = fringe benefit cost
X7 = cost of hiring a staff member
X8 = cost of resignation
X9 = cost of a transfer

170 - 175 Computes various totals.

```
ISN   SISSCN - SCONE -                      FORTRAN SOURCE LIST
SN          SOURCE STATEMENT

 0 $IBFTC DEMC
 1          SUBROUTINE DEMC
 2          INTEGER T,STARTM,STOPTM,RO
 3          COMMON/MASTER/T,STARTM,STOPTM,RC,DOLCEQ,EPS,EL,TDOLEQ
 4          COMMON /CDEMO/ POP,STU(2),STFA(2),STFN(2),CSTF(2)
 5          COMMON/CSTUP/IYF(4),STUF(4,2)
 6          COMMON/XDEMO/X1(2),X2(2),X3(2),X4(2),X5(2),X6(2),X7(2),X8(2),
           1X9(2),X1C(2),X11(2),PINF
 7          COMMON/CPDM/ CPS,PSTFA(2),WUCP(2)
 10         DIMENSION STFI(2),STFO(2),STFH(2),STFL(2),STFAF(2),DIFF(2)
 11         DIMENSION STFAX(2), DCFAC(2) ,SP(2)
 12         HLIM=2CCC.
 13         IF(T.GT.C)GO TO 41
 16         READ(5,9)((IYF(I),STUF(I,1),STUF(I,2)),I=1,4)
 27 9       FORMAT(4(I2,2F6.0))
 30         READ(5,1)((X1(I),X2(I),X3(I),X4(I),X5(I),X6(I),X7(I),X8(I),X9(I),
           1X1C(I),X11(I)),I=1,2)
 41 1       FORMAT(11F6.C)
 42         READ(5,2)(STFAX(I),I=1,2)
 47 2       FORMAT(2F6.0)
 50         DO 14 I=1,2
 51 14      STFN(I)=X2(I)*STUF(1,I)
 53         DO 15 I=1,2
 54      15 SP(I)=.1C
 56         CALL PDEMO
 57         RETURN
 60    41   IIT=T-STARTM
 61         IF(T.NE.STARTM) GO TO 3
 64         DO 40 I=1,2
 65    40   STFA(I)=STFAX(I)
 67          DO 1CC I=1,2
 70   100   STFN(I)=X2(I)*STUF(1,I) +SP(I)*PSTFA(I)
 72 3       DO 1C I=2,4
 73          IF(T.GT.IYF(I))GO TO 10
 76          FR=FLOAT(T-IYF(I-1))/5.
 77          DO 11 J=1,2
100 11       STU(J)=FR*STUF(I,J)+(1.0-FR)*STUF(I-1,J)
102          GO TO 12
103 1C       CONTINUE
105          DO 13 J=1,2
106          RL=(STUF(4,J)-STUF(3,J))/5.
107 13       STU(J)=STUF(4,J)+FLOAT(T-IYF(4))*RL
111      12 IF (PINF.EQ.C.) GO TO 25
114          DO 2C I=1,2
115      20 STU(I)=STU(I)*((1.+PINF)**IIT)
117      25 POP=STU(1)+STU(2)
120          DO 60 I=1,2
121          STFI(I)=C.0
122          STFO(I)=C.C
123          STFL(I)=X3(I)*STFA(I)
124      60 STFH(I)=X4(I)*(STFN(I)-STFA(I)+STFL(I))
126          TSTFH=STFH(1)+STFH(2)
127          IF (TSTFH.LE.HLIM) GO TO 55
132          DO 5C I=1,2
133      5C STFH(I)= (STFH(I)/TSTFH)*HLIM
```

```
015  SISSCN - SCONE -                    FORTRAN SOURCE LIST DEMO
SN        SOURCE STATEMENT

35   55   CALL PDEMO
36        DO 5 I=1,2
37        IF(STFH(I).LT.0.0)STFH(I)=0.0
42        STFN(I)=X2(I)*STU(I)    +SP(I)*PSTFA(I)      (See Note)
43        STFAF(I)=STFA(I)+STFH(I)-STFL(I)
44 5      DIFF(I)=STFAF(I)-STFN(I)
46        XT=DIFF(1)*DIFF(2)
47        IF(XT.GE.0.0)GO TO 7
52        IF(DIFF(1).GT.0.0)GO TO 6
55        DIFF(1)=-DIFF(1)
56        STFI(1)=X5(1)*AMIN1(DIFF(1),DIFF(2))
57        STFO(2)=STFI(1)
60        GO TO 7
61    6   DIFF(2)=-DIFF(2)
62        STFI(2)=X5(2)*AMIN1(DIFF(1),DIFF(2))
63        STFO(1)=STFI(2)
64    7   DO 8 I=1,2
65        STFA(I)=STFAF(I)+STFI(I)-STFO(I)
66        ITT=T-STARTM+1
67        DCFAC(I)=((1.+X10(I))**ITT)*(X6(I)+X11(I))
70   8    CSTF(I)=DCFAC(I)*STFA(I)+X7(I)*STFH(I)+X8(I)*STFL(I)+
         1X9(I)*(STFI(I)+STFO(I))
72        STFNT=STFN(1)+STFN(2)
73        STFAT=STFA(1)+STFA(2)
74        STFHT=STFH(1)+STFH(2)
75        STFLT=STFL(1)+STFL(2)
76        STR=PCP/STFAT
77        RETURN
200       END
```

Note: In CAI runs XE2 is used here instead of X2.
XE2 is calculated in subroutine EQPURC.

PDEMO (This subroutine called from DEMO where paraprofessional staff is to be hired.)

1 - 6	Set up core.
7 - 22	Set up parameters before first run (T = 0).
23 - 26	Compute parastaff hired: I = area index PSTFA = parastaff available PSTFL = parastaff resignations (a proportion, PL, of parastaff available at end of year) PH = staff hired PX2 = parastaff/student ratio, policy
30 - 35	Limits total hires per year to PLIM
37 - 43	Computes cost of paraprofessional staff UCP = average salary including fringe benefits PPINF = inflation rate of paraprofessional salaries WUCP = total cost in area CPS = total cost

015 SISSCN - SCONE - FORTRAN SOURCE LIST

ISN SOURCE STATEMENT

```
$IBFTC PDEMO
      SUBROUTINE PDEMO
      INTEGER T,STOPTM,STARTM,RO
      COMMON/MASTER/T,STARTM,STOPTM,RO,DOLCEQ,EPS,EL,TDOLEQ
      COMMON /CDEMC/ POP,STU(2),STFA(2),STFN(2),CSTF(2)
      COMMON/CPDM/ CPS,PSTFA(2),WUCP(2)
      DIMENSION PL(2), UCP(2), PX2(2)  ,PSTFL(2)  ,  PH(2)
      IF(T.GT.0) GO TO 1
      DO 3 I=1,2
      PL(I)=.3
      PLIM=7000.
      UCP(I)=5000.
      PX2(I)=.2
    3 PSTFA(I)=0.
      PPINF=.03
      RETURN
    1 ITT=T-STARTM
      DO 2 I=1,2
      PSTFL(I)=PL(I)*PSTFA(I)
    2 PH(I)=(PX2(I)*STU(I) )-PSTFA(I)+PSTFL(I)
      PT=PH(1)+PH(2)
      IF (PT.LT.PLIM) GO TO 4
      DO 5 I=1,2
    5 PH(I)=(PH(I)/PT)*PLIM
    4 DO 6 I=1,2
      PSTFA(I)= PSTFA(I)+PH(I) -PSTFL(I)
    6 WUCP(I)=UCP(I)*((1.+PPINF)**ITT) *PSTFA(I)
      CPS=WUCP(1)+WUCP(2)
      RETURN
      END
```

CONST 1

1 - 21	Set up core
22 - 271	Read in initial parameters and values.
272	Call CONST 2 to allow its initial values to be read.
274 - 320	Re-estabilish values for next run.
323 - 325	Calculate cost inflation factor CFAC based on annual increase CINF and years after start IIT.
326 - 331	Calculate cost of units: TCNEW = new schools, TCAAD = additions, TCREP = a standard unit of repair; for 5 types of space.
333 - 342	Compute number of units now in system NUMNEW, etc. based on preplanned program (1966, 6-year capital program).
344	If year (since start) MMT is greater than last year of capital programLFLAG, call CONST 2 for continuing the construction process (CONST 2 returns with new NUMNEW).
347 - 440	Compute cost DOLNEW, etc., of construct for the year. DOLANN is the overall total: DOT (1) = cost of new construction, DOL = Cost of additions and repairs.
441 - 527	Compute total square feet FT2NET = total square feet in the system.
532 - 600	Adjusts data for next year.

```
015  SISSCN - SDONE -                    FORTRAN SOURCE LIST                                  0
SN        SOURCE STATEMENT

 $IBFTC CONST1
          SUBROUTINE CONST1
          INTEGER T,STARTM,STOPTM,RO
          COMMON/MASTER/T,STARTM,STOPTM,RO,DOLCEQ,EPS,EL,TDOLEQ
          COMMON /CON01/ DOLANN,DTOT(5),DCL,FT2NET     ,BC(40),FSR
          COMMON/CON02/ NUMNEW,NUMADD,NUMREP,NDEMC
          COMMON/CON03/ SP1,SP2,SP3,SPD
          COMMON/CON04/ TCNEW,TCADD,TCREP
          COMMON/CON05/ FRDOLN,FRDOLA,FRDOLR
       10 FORMAT(40I2)
       11 FORMAT(5F10.0)
       13 FORMAT(F10.0)
       14 FORMAT(20F5.0)
       20 FORMAT(7I5)
          DIMENSION AA1(5,2),TXNEW(5),TXADD(5),TXREP(5)
          DIMENSION MAXN(5), MAXA(10), MAXR(5)
          DIMENSION NUMN(5,40),NUMA(5,40),NUMR(5,40),NDEMO(5,40),FRDOLN(5,5)
        1 ,FRDOLA(10,5),FRDOLR(5,5),TCNEW(5),TCADD(10),TCREP(5),AFACTR(5),
        2   SPINIT(10),SPFRN(5,10),SPFRR(5,10),SPFRD(5,10),SP1(5),SP2(10),
        3   SP3(5),SPD(5),NUMNEW(5,5),NUMADD(10,5),NUMREP(5,5),DOLNEW(5,5),
        4   DOLADD(10,5),DOLREP(5,5),DSUMN(5),DSUMA(10),DSUMR(5),
        5   SPNEW(5),SPADD(10),SPREP(5),ADDSPN(5,10),ADDSPR(5,10),ADDN(10),
        6   ADDR(10),ASPACE(10),MDEMOL(5),SPDEM(5),SUBD(10),SPANET(10)
          DIMENSION  SPANX(10), NUMNX(5,5), NUMAX(10,5), NUMRX(5,5)
          IF(T .NE. 0) GO TO 100
          NPER = STOPTM - STARTM+1
          READ(5,20) NNMAX,NAMAX,NRMAX,MAXSTN,MAXSTA,MAXSTR,LFLAG
          DO 40 I=1,NNMAX
       40 READ(5,10) (NUMN(I,J),J=1,NPER)
          DO 45 I=1,NAMAX
       45 READ(5,10) (NUMA(I,J),J=1,NPER)
          DO 50 I=1,NRMAX
       50 READ(5,10) (NUMR(I,J),J=1,NPER)
          DO 55 I=1,NNMAX
       55 READ(5,11) (FRDOLN(I,J),J=1,MAXSTN)
          DO 60 I=1,NAMAX
       60 READ(5,11) (FRDOLA(I,J),J=1,MAXSTA)
          DO 65 I=1,NRMAX
       65 READ(5,11) (FRDOLR(I,J),J=1,MAXSTR)
          READ(5,11) (TXNEW(I),I=1,5)
          READ(5,11) (TXADD(I),I=1,5)
          READ(5,11) (TXREP(I),I=1,5)
          READ(5,13) AFACTR(1)
          READ(5,11) (SPANX (J),J=1,5)
          FT2NET = 0.0
          DO 68 J=1,NAMAX
       68 FT2NET = FT2NET + SPANET(J)
          READ(5,10) (MAXN(I),I=1,5),(MAXA(I),I=1,10),(MAXR(I),I=1,5)
          DO 70 I=1,NRMAX
       70 READ(5,10) (NDEMO(I,J),J=1,NPER)
          DO 75 I=1,NNMAX
       75 READ(5,14) (SPFRN(I,J),J=1,NAMAX)
          DO 80 I=1,NRMAX
       80 READ(5,14) (SPFRR(I,J),J=1,NAMAX)
          DO 85 I=1,NRMAX
```

```
015  SISSCN - SDONE -                     FORTRAN SOURCE LIST CONST1
SN        SOURCE STATEMENT

04     85 READ(5,14) (SPFRD(I,J),J=1,NAMAX)
12        READ(5,11) (SP1(I),I=1,5)
17        READ(5,11) (SP2(I),I=1,5)
24        READ(5,11) (SP3(I),I=1,5)
31        READ(5,11) (SPD(I),I=1,5)
   C      INITIAL CONDITIONS
36        READ(5,10) ((NUMNX (I,J),J=2,5),I=1,NNMAX)
47        READ(5,10) ((NUMAX (I,J),J=2,5),I=1,NAMAX)
60        READ(5,10) ((NUMRX (I,J),J=2,5),I=1,NRMAX)
71        CINF=.025
72        CALL CONST2
73        GO TO 400
   C      T IS GREATER THAN ZERO
74    100 IF(T.NE.STARTM) GO TO 200
77        FT2NET=0.
00        DO 101 J=1,5
01        SPANET(J)=SPANX(J)
02    101 FT2NET=FT2NET+SPANET(J)
04        DO 102 I=1,NNMAX
05        DO 102 J=2,5
06    102 NUMNEW(I,J)=NUMNX(I,J)
11        DO 103 I=1,NAMAX
12        DO 103 J=2,5
13    103 NUMADD(I,J)=NUMAX(I,J)
16        DO 104 I=1,NRMAX
17        DO 104 J=2,5
20    104 NUMREP(I,J)=NUMRX(I,J)
23    200 MMT = T - STARTM+1
   C ADJUST FOR INFLATION
24        IIT=T-STARTM
25        CFAC=(1.+CINF)**IIT
26        DO 105 I=1,5
27        TCNEW(I)=TXNEW(I)*CFAC
30        TCADD(I)=TXADD(I)*CFAC
31   105  TCREP(I)=TXREP(I)*CFAC
33        DO 205 I=1,NNMAX
34    205 NUMNEW(I,1) = NUMN(I,MMT)
36        DO 206 I=1,NAMAX
37    206 NUMADD(I,1) = NUMA(I,MMT)
41        DO 207 I=1,NRMAX
42    207 NUMREP(I,1) = NUMR(I,MMT)
44        IF(MMT .GT. LFLAG) CALL CONST2
47        DO 215 J=1,MAXSTN
50        DO 210 I=1,NNMAX
51    210 DOLNEW(I,J) = FLOAT(NUMNEW(I,J))*TCNEW(I)*FRDOLN(I,J)
53    215 CONTINUE
55        DO 220 J=1,MAXSTA
56        DO 216 I=1,NAMAX
57    216 DOLADD(I,J) = FLOAT(NUMADD(I,J))*TCADD(I)*FRDOLA(I,J)
61    220 CONTINUE
63        DO 225 J=1,MAXSTR
64        DO 221 I=1,NRMAX
65    221 DOLREP(I,J) = FLOAT(NUMREP(I,J))*TCREP(I)*FRDOLR(I,J)
67    225 CONTINUE
71        DO 230 I=1,NNMAX
```

```
ISN       SOURCE STATEMENT

372            DSUMN(I) = 0.
373            DO 226 J=1,MAXSTN
374        226 DSUMN(I) = DSUMN(I) + DOLNEW(I,J)
376        230 CONTINUE
400            DO 235 I=1,NAMAX
401            DSUMA(I) = 0.
402            DO 231 J=1,MAXSTA
403        231 DSUMA(I) = DSUMA(I) + DOLADD(I,J)
405        235 CONTINUE
407            DO 240 I=1,NRMAX
410            DSUMR(I) = 0.
411            DO 236 J=1,MAXSTR
412        236 DSUMR(I) = DSUMR(I) + DOLREP(I,J)
414        240 CONTINUE
416            DTOT(1) = 0.
417            DO 241 I=1,NNMAX
420        241 DTOT(1) = DTOT(1) + DSUMN(I)
422            DTOT(2) = 0.
423            DO 242 I=1,NAMAX
424        242 DTOT(2) = DTOT(2) + DSUMA(I)
426            DTOT(3)=0.
427            DO 243 I=1,NRMAX
430        243 DTOT(3)=DTOT(3)+DSUMR(I)
432            DUMMY=0.
433            DO 245 K=1,3
434        245 DUMMY = DUMMY+DTOT(K)
436            DTOT(4)= AFACTR(1)*DUMMY
437            DOL = DTOT(4) + DTOT(2) + DTOT(3)
440            DOLANN = DUMMY + DTOT(4)
      C        CALCULATION OF SPACE CHANGES THIS PERIOD
441            DO 270 I=1,NNMAX
442            K=MAXN(I)
443        270 SPNEW(I) = FLOAT(NUMNEW(I,K       ))*SP1(I)
445            DO 275 I=1,NAMAX
446            K=MAXA(I)
447        275 SPADD(I) = FLOAT(NUMADD(I,K       ))*SP2(I)
451            DO 280 I=1,NRMAX
452            K=MAXR(I)
453        280 SPREP(I) = FLOAT(NUMREP(I,K       ))*SP3(I)
455            DO 290 I=1,NNMAX
456            DO 285 J=1,NAMAX
457        285 ADDSPN(I,J) = SPNEW(I)*SPFRN(I,J)
461        290 CONTINUE
463            DO 295 I=1,NRMAX
464            DO 291 J=1,NAMAX
465        291 ADDSPR(I,J) = SPREP(I)*SPFRR(I,J)
467        295 CONTINUE
471            DO 305 J=1,NAMAX
472            ADDN(J)=0.
473            DO 301 I=1,NNMAX
474        301 ADDN(J) = ADDN(J) + ADDSPN(I,J)
476            ADDR(J)=0.
477            DO 303 I=1,NRMAX
500        303 ADDR(J) = ADDR(J) + ADDSPR(I,J)
502        305 CONTINUE
```

```
      SOURCE STATEMENT

      DO 310 J=1,NAMAX
  310 ASPACE(J) = ADDN(J) + SPADD(J) + ADDR(J)
      DO 315 I=1,NRMAX
      NDEMOL(I) = NDEMO(I,MMT)
  315 SPDEM(I) = FLOAT(NDEMOL(I))*SPD(I)
      DO 325 J=1,NAMAX
      SUBD(J)=0.
      DO 320 I=1,NRMAX
  320 SUBD(J) = SPDEM(I)*SPFRD(I,J)+SUBD(J)
  325 CONTINUE
      DO 330 J=1,NAMAX
  330 SPANET(J) = ASPACE(J) - SUBD(J)
      FT2TOT = 0.0
      DO 340 J=1,NAMAX
  340 FT2TOT = FT2TOT + SPANET(J)
      FT2NET = FT2NET + FT2TOT
C     SHIFTING TO GO TO NEXT PERIOD
      DO 365 I=1,NNMAX
      K=MAXN(I)
      IF(K .LT. 2) GO TO 365
      DO 360 J = 1,K
      M = K - J
      IF(M .EQ. 0) GO TO 365
  360 NUMNEW(I,M+1) = NUMNEW(I,M)
  365 CONTINUE
      DO 375 I=1,NAMAX
      K=MAXA(I)
      IF(K .LT. 2) GO TO 375
      DO 370 J = 1,K
      M = K - J
      IF(M .EQ. 0) GO TO 375
  370 NUMADD(I,M+1) = NUMADD(I,M)
  375 CONTINUE
      DO 385 I=1,NRMAX
      K=MAXR(I)
      IF(K .LT. 2) GO TO 385
      DO 380 J = 1,K
      M = K - J
      IF(M .EQ. 0) GO TO 385
  380 NUMREP(I,M+1) = NUMREP(I,M)
  385 CONTINUE
  400 RETURN
      END
```

CONST 2

1 - 20	Set up core
21 - 50	Set up initial conditions 24 - 36 Computes crude parameters for forecasting enrollment by a linear extrpolation; with constant A1 and slope B1. This is based on the past two years.
51 - 53	Compute enrollment APF3 from A1 and B1. Add paraprofessional staff, PSTFA, who also need space. (Staff needs are assumed to be negligible at this level of aggregation.)
54 - 73	Calculate space available, YYY, from construction previously authorized, in year being planned. SPI is space per unit.
74 - 75	If space available exceeds policy requirements, return.
100 - 155	Calculate cost of construction in process for years under planning (next three). DXXX (K) is total cost in year K.
157 - 163	Compare cost to budget BC (K). If exceeded, return, otherwise go on to add construction.
165 - 176	See if new construction will exceed budget. If so, → if not go on (Note that one school over budget can be authorized).
203	NY = added school
204 - 206	If space exceeded →
211 - 212	Add schools of each level (elementary, middle, high) and then repeat (at statement 392) until one of the limits is exceeded. Here 4 elementary schools are needed.
215 - 222	Check cost
224 - 243	Add two middle schools
245 - 253	Add one high school
255 - 256	Update new school count for years under consideration
261	Return to main construction simulation CONST 1. ←

```
ISN       SOURCE STATEMENT

  0 $IBFTC CONST2
  1         SUBROUTINE CONST2
  2         INTEGER T,STARTM,STOPTM,RO
  3         COMMON/MASTER/T,STARTM,STOPTM,RO,DOLCEQ,EPS,EL,TDOLEQ
  4         COMMON/CSTUP/IYF(4),STUF(4,2)
  5         COMMON /CONC1/ DOLANN,DTOT(5),DOL,FT2NET     ,BC(40),FSR
  6         COMMON/CONO2/ NUMNEW,NUMADD,NUMREP,NDEMO
  7         COMMON/CONO3/ SP1,SP2,SP3,SPD
 10         COMMON/CONO4/ TCNEW,TCADD,TCREP
 11         COMMON/CONO5/ FRDOLN,FRDOLA,FRDOLR
 12         COMMON /CDEMO/ POP,STU(2),STFA(2),STFN(2),CSTF(2)
 13         COMMON/CPDM/ CPS,PSTFA(2),WUCP(2)
 14         DIMENSION NUMNEW(5,5),NUMADD(10,5),NUMREP(5,5),NDEMO(5,40),SP1(5),
          1    SP2(10),SP3(5),SPD(5),TCNEW(5),TCADD(10),TCREP(5), FRDOLN(5,5),
          2    FRDOLA(10,5),FRDOLR(5,5)
 15         DIMENSION A1(3),B1(3),         DNUC(5,3),DRUC(5,3),DAUC(10,3),
          1    DN(3),DR(3),DA(3),DXXX(3),NX(3),CST(3)
 16         DIMENSION PF(4), IYPF(4)
 17      10 FORMAT(8F10.0)
 20      11 FORMAT(F10.0)
 21         IF(T .GT. 0) GO TO 300
 24         DO 80 J = 1,4
 25         IYPF(J) = IYF(J)
 26         PF(J) = 0.0
 27         DO 75 I = 1,2
 30      75 PF(J) = PF(J) + STUF(J,I)
 32      80 CONTINUE
 34         DO 100 I=1,3
 35         B1(I) = (PF(I+1)-PF(I))/FLOAT(IYPF(I+1)-IYPF(I))
 36         A1(I) = PF(1) - B1(I)*FLOAT(IYPF(I))
 37     100 CONTINUE
 41         NPER = STOPTM - STARTM + 1
 42         READ(5,10) (BC(I),I=1,40)
 47         READ(5,11) FSR
 50         GO TO 500
      C     T IS GREATER THAN ZERO
 51     300 JJT = T + 2
 52         LL1 = ((JJT - IYPF(1))/5) + 1
 53         APF3 = A1(LL1) + B1(LL1)*FLOAT(JJT) +PSTFA(1)+PSTFA(2)
          1+STFA(1)+STFA(2)
      C     CALCULATE FLOOR SPACE IN THREE YEARS
 54         UCH = FLOAT(NUMNEW(1,3)+NUMNEW(1,4)+NUMNEW(1,5))*SP1(1)
 55         UCI = FLOAT(NUMNEW(2,2)+NUMNEW(2,3)+NUMNEW(2,4))*SP1(2)
 56         UCL = FLOAT(NUMNEW(3,1)+NUMNEW(3,2)+NUMNEW(3,3))*SP1(3)
 57         UCA = 0.0
 60         DO 310 I=1,5
 61         DO 309 J=1,3
 62     309 UCA = UCA + FLOAT(NUMADD(I,J))*SP2(I)
 64     310 CONTINUE
 66         LLT = T - STARTM + 1
 67         UCHR = FLOAT(NUMREP(1,3) + NUMREP(1,4)+NUMREP(1,5))*SP3(1) -
          1    FLOAT(NDEMO(1,LLT+2)+NDEMO(1,LLT+1)+NDEMO(1,LLT))*SPD(1)
 70         UCIR = FLOAT(NUMREP(2,2) + NUMREP(2,3)+NUMREP(2,4))*SP3(2) -
          1    FLOAT(NDEMO(2,LLT+2)+NDEMO(2,LLT+1)+NDEMO(2,LLT))*SPD(2)
 71         UCLR = FLOAT(NUMREP(3,1) + NUMREP(3,2)+NUMREP(3,3))*SP3(3) -
```

```
ISN     SOURCE STATEMENT

      1   FLOAT(NDEMO(3,LLT+2)+NDEMO(3,LLT+1)+NDEMO(3,LLT))*SPD(3)
          XXX = UCH + LCA + LCL + UCA + UCHR + UCIR + UCLR
          YYY = FT2NET + XXX
          RATIO1 = YYY/AFF3
          IF(RATIO1 .GT. FSR) GO TO 500
C         CALCULATE TOTAL EXPENDITURES FOR THIS AND THE NEXT 2 YEARS
C         NEW AND REPLACEMENTS
          DO 330 I=1,3
          LL5 = 7 - I
          DO 325 K=1,3
          DNUC(I,K) = 0.0
          DRUC(I,K) = 0.0
          JMAX1 = LL5 - K
          LL4 = K - 1
          DO 320 J=1,JMAX1
          MZ = J + LL4
          DNUC(I,K) = DNUC(I,K)+ FLOAT(NUMNEW(I,J))*TCNEW(I)*FRDOLN(I,MZ)
          DRUC(I,K) = DRUC(I,K)+FLOAT(NUMREP(I,J))*TCREP(I)*FRDOLR(I,MZ)
      320 CONTINUE
      325 CONTINUE
      330 CONTINUE
C         ADDITIONS
          DO 345 I=1,5
          DO 340 K=1,3
          DAUC(I,K) = 0.0
          JMAX1 = 4 - K
          LL4 = K - 1
          DO 335 J=1,JMAX1
          MZ = J + LL4
          DAUC(I,K) = DAUC(I,K)+FLOAT(NUMADD(I,J))*TCADD(I)*FRDOLA(I,MZ)
      335 CONTINUE
      340 CONTINUE
      345 CONTINUE
C         SUMMING ACROSS ALL SCHOOL TYPES
          DO 360 K=1,3
          DN(K) = 0.0
          DR(K) = 0.0
          DO 350 I=1,3
          DN(K) = DN(K) + DNUC(I,K)
      350 DR(K) = DR(K) + DRUC(I,K)
          DA(K) = 0.0
          DO 355 I=1,5
      355 DA(K) = DA(K) + DAUC(I,K)
      360 CONTINUE
C         SUMMING ACROSS ALL CONST TYPES
          DO 365 K=1,3
      365 DXXX(K) = DN(K) + DR(K) + DA(K)
          DO 370 K=1,3
          IF(DXXX(K) .GT. BC(LLT)) GO TO 500
      370 CONTINUE
C         ADD SOME NEW SCHOOLS
          FXXX = 0.0
          DO 385 J=1,3
          CST(J) = 0.0
      385 NX(J) = 0
```

015 SISSCN - SCONE - FORTRAN SOURCE LIST CONST2

```
ISN      SOURCE STATEMENT

    391 MXX1 = 0
        MXX2 = 0
    392 DO 395 K=1,3
        CST(K) = CST(K) + TCNEW(3)*FRDOLN(3,K)
        IF((DXXX(K)+CST(K)) .GT. BC(LLT)) GO TO 430
    395 CONTINUE
        NX(3) = NX(3) + 1
        FXXX = FXXX + SP1(3)
        RATIO2 = (YYY + FXXX) / APF3
        IF(RATIO2 .GT. FSR) GO TO 435
        MXX1 = MXX1 + 1
        IF(MXX1 .LT. 4) GO TO 392
    396 DO 400 K=1,3
        CST(K) = CST(K) + TCNEW(2)*FRDOLN(2,K)
        IF((DXXX(K)+CST(K)) .GT. BC(LLT)) GO TO 430
    400 CONTINUE
        NX(2) = NX(2) + 1
        FXXX = FXXX + SP1(2)
        RATIO2 = (YYY + FXXX) / APF3
        IF(RATIO2 .GT. FSR) GO TO 435
        MXX2 = MXX2 + 1
        IF(MXX2 .LT. 2) GO TO 396
        DO 405 K=1,3
        CST(K) = CST(K) + TCNEW(1)*FRDOLN(1,K)
        IF((DXXX(K)+CST(K)) .GT. BC(LLT)) GO TO 430
    405 CONTINUE
        NX(1) = NX(1) + 1
        FXXX = FXXX + SP1(1)
        RATIO2 = (YYY + FXXX) / APF3
        IF(RATIO2 .GT. FSR) GO TO 435
        GO TO 391
C       BUDGET CONSTRAINT REACHED
    430 GO TO 435
C       DESIRED SPACE REACHED
    435 DO 440 I=1,3
        NUMNEW(I,1) = NUMNEW(I,1) + NX(I)
    440 CONTINUE
    500 RETURN
        END
```

<u>OPNS</u>	Computes overheads.
1 - 10	Set up core
11 - 34	Read in overhead factors and initial rates.
35 - 37	I = factor index FLATN(I) = inflation factor for this year, TBASE, years after start.
41 - 51	THLTH = cost of health services RIHLTH, R2HLTH = average health service cost per student in each eara TTA = transportation cost RITTA, R2TTA = average transportation cost per student TCNSER = contract service cost RINSR = average contract service cost per student R2CNSR = average contract service cost per square foot of building space TBKSED = cost of books and educational materials R1BE, R2BE = average cost of books, etc., per student PERC = percent of students using CAI equipment TEQ = equipment related costs RIEQ = equipment related costs per student with CAI (assumed to be 1/10th as great without CAI). TRMEQ = equipment maintenance and repair costs RRMEQ = cost of maintenance per dollars worth of equipment TDS = debt service cost DOLANN = capital dollars spent this year DFACT = average debt service per capital dollar expended.
52	Total overhead, TOH.

```
015   SISSCN - SDONE -                     FORTRAN SOURCE LIST
ISN       SOURCE STATEMENT

  0 $IBFTC OPNS
  1       SUBROUTINE OPNS
  2       INTEGER T,STARTM,STOPTM,RC
  3       COMMON/COPNS/TPOM,TEQ,TBKSED,TTA,THLTH,TRMEQ,TDS,TCNSER,TOH
         1,R1EQ,R2EQ
  4       COMMON/CDEMO/POP,STU(2),STFW(2),STFN(2),CSTF(2)
  5       COMMON /CONC1/ DOLANN,DTOT(5),DOL,FT2NET     ,BC(40),FSR
  6       COMMON/MASTER/T,STARTM,STOPTM,RC,DOLCEQ,EPS,EL,TDOLEQ
  7       DIMENSION R(10),FLATN(10)
 10       INTEGER TBASE
 11       IF(T.GT.0)GO TO 8
 14       READ (5,4) (R(I),I=1,7)
 21     4 FORMAT (7F4.3)
 22     6 FORMAT(2F6.3)
 23       READ(5,6)R1HLTH,R2HLTH
 24       READ(5,6)R1TTA,R2TTA
 25       READ(5,6)R1BE,R2BE
 26       READ(5,6)R1EQ,R2EQ
 27       READ(5,6)R1CNSR,R2CNSR
 30     7 FORMAT(F7.4)
 31       READ(5,7)DFACT
 32       READ(5,7)RPOM
 33       READ(5,7)RRMEQ
 34       TDS = 10.E6
 35       TDOLEQ = 12.E6
 36       RETURN
 37     8 TBASE=T-STARTM
 40       DO 5 I=1,10
 41     5 FLATN(I)=(1.0+R(I))**TBASE
 43       THLTH=(R1HLTH*STU(1) + R2HLTH*STU(2))*FLATN(1)
 44       TTA=(R1TTA*STU(1) + R2TTA*STU(2))*FLATN(2)
 45       TCNSER = (R1CNSR*POP+R2CNSR*FT2NET)*FLATN(3)
 46       TBKSED=(R1BE*STU(1) + R2BE*STU(1))*FLATN(4)
 47       TEQ=(R1EQ*STU(1) + R2EQ*STU(2))*FLATN(5)
 50       TRMEQ = RRMEQ*TDOLEQ*FLATN(6)
 51       TPOM = RPOM*FT2NET*FLATN(7)
 52       TDS = DOLANN*DFACT+TDS
 53       TOH=TPOM+TEQ+TBKSED+TTA+THLTH+TRMEQ+TDS+TCNSER
 54       RETURN
 55       END
```

EQPURC

1 - 7	Set up core
10 - 17	Reset parameters for each run (when T = STARTM)
20 - 60	Compute equipment expenditure DOLCEQ which must be less than the budget limit EL.

EPS = Equipment (capital cost) required per student for CAI.
POP = total enrollment.

Calculate share of budget for equipment for area 2 (which is weighted by a factor FS to be proportionately greater than area 1).

I = area index
E = total capital needed in area
DOL = capital spent this year
TDOL = capital for CAI spent to date
TODLEQ = total capital spent to date
XW2 = effective staff student ratio: varies between the basic ratio, X2, and the rate with CAI, XC2, in proportion to the fraction of students on CAI.
PERC = percent of students using CAI.

025 SISSON SDCAI FORTRAN SOURCE LIST

```
ISN        SOURCE STATEMENT

  0 $IBFTC EQPURC
  1          SUBROUTINE EQPURC
  2          INTEGER T, STARTM
  3          REAL M
  4          COMMON/MASTER/T,STARTM,STOPTM,RO,DOLCEQ,EPS,EL,TDOLEQ
  5          COMMON /CDEMO/ POP,STU(2),STFA(2),STFN(2),CSTF(2)
  6          COMMON /CEQ/ FS,XE2(2),XC2(2),X2(2),PERC
  7          DIMENSIONDOL(2),TDOL(2),E(2)
 10          IF (T.NE.STARTM) GO TO 1
 13          DO 2 I=1,2
 14        2 XE2(I)=X2(I)
 16          TDOL(1)=0.
 17          TDOL(2)=0.
 20        1 DOLCEQ = EPS*POP
 21          IF (DOLCEQ .GT. EL) DOLCEQ = EL
 24          DO 10 I=1,2
 25       10 E(I)=EPS*STU(I)
 27        3 DOL(2)=(1./FS)*DOLCEQ*(STU(2)/POP)
 30          IF (DOL(2).GT.DOLCEQ) DOL(2)=DOLCEQ
 33          TDOL(2)=TDOL(2)+DOL(2)
 34          IF (TDOL(2).LT.E(2)) GO TO 11
 37          TDOL(2)=E(2)
 40          DOL(2)=E(2)-TDOL(2)+DOL(2)
 41       11 DOL(1)=DOLCEQ-DOL(2)
 42          TDOL(1)=TDOL(1)+DOL(1)
 43          IF (TDOL(1).LT.E(1)) GO TO 4
 46          TDOL(1)=E(1)
 47          DOL(1)=E(1)-TDOL(1)+DOL(1)
 50          DOLCEQ=DOL(1)+DOL(2)
 51        4 DO 5 I=1,2
 52        5 XE2(I)=(TDOL(I)/E(I))*XC2(I)+((E(I)-TDOL(I))/E(I))*X2(I)
 54          PERC=((TDOL(1)+TDOL(2)) /(E(1)+E(2))) *100.
 55          TDOLEQ=TDOLEQ+DOLCEQ
 56          WRITE(6,100) DOL(1),DOL(2),TDOL(1),TDOL(2),E(1),E(2)
 57      100 FORMAT (1H0/1H0,6(2X,F10.0)//)
 60          RETURN
 61          END
```