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ABSTRACT

This paper describes a series of heuristic approaches to helping schools analyze problems by the use of a teletype time-sharing computer terminal. The examples detailed include 1) a Delphi exercise for students; 2) a budgeting model which examines the results of various levels of funding and of changes of relative priorities; 3) a school redistricting problem which was formulated as a linear programming problem to provide the best possible solution within existing constraints; 4) an analysis of data to provide the optimum use of facilities; and 5) a technique for exploring the activities that should occur in a school being planned, adding the perceived roles of staff. While better models are being created and made available, these heuristic approaches offer a useful way to help school personnel gain insights into their problems of management and planning and to find out the effects of various proposed actions on a "while you wait" basis. Samples of the computer printout for each of the examples described are included in the document. (MBM)

26.2

HEURISTICS: A STEP TOWARD GETTING THERE

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April 1, 1972

HEURISTICS: A STEP TOWARD GETTING THERE

heu·ris'tic: serving to discover or to stimulate investigation.

- *Webster's Collegiate Dictionary*, 1943

heuristics: techniques or procedures for varying search, choice, or discovery operations to permit the progressive resolution of difficult problems; if the heuristics are applicable they will provide a short-cut to a goal; heuristic methods cannot guarantee solution to complex problems.

- Granger, R.L. *Educational Leadership*. Intext, 1971. P. 30

A well-known paradox in bringing about systems changes is that you need your greatest expertise before you have had any real chance to acquire it. Modeling in Education faces a form of that paradox today. On the one hand is the demand for performance, accountability and even optimization. On the other hand are the claims that our models are incomplete, hard to get data for, difficult to use, limited in applicability, focused on the wrong problems, unable to provide timely solutions, prone to suggest solutions that are unacceptable (or, at least, unpopular), and, occasionally, simply irrelevant. Yet, the modeling process in other fields of human endeavor has given results such as better management, greater profits, and improved transportation and communication. In short, a rationale for decision-making based on a serious modeling effort has developed and gained acceptance.

Time will remedy some aspects of this situation. Better models will be developed and tested, and educators will gain understanding of how and when to use them. Meanwhile, education does have real and immediate problems. The purpose of this paper is to present several instances where techniques in the spirit of operations research but short of formal modeling have proved useful.

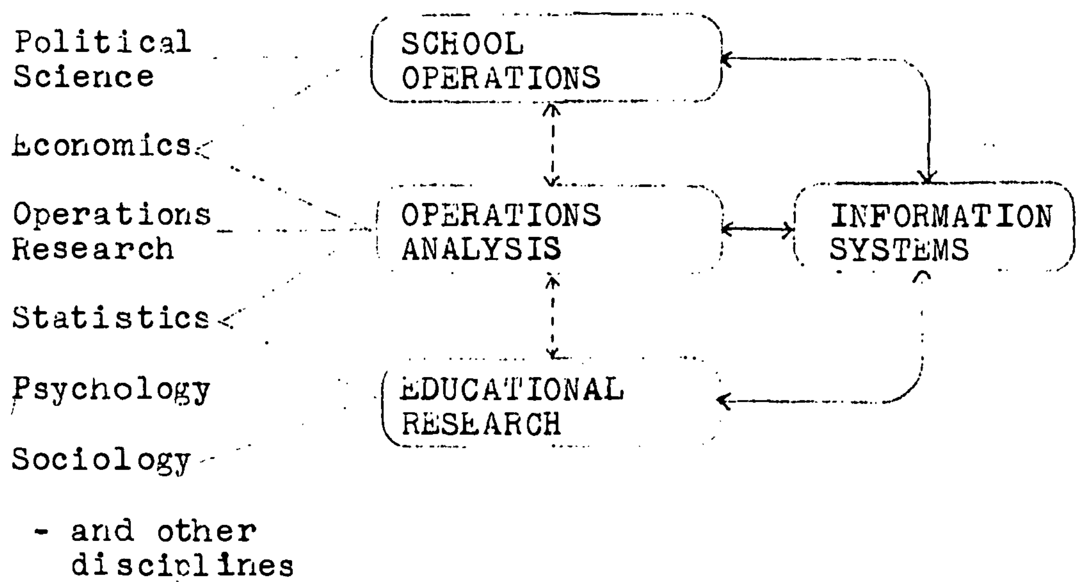

Exhibit 1: The Operations Analysis-Information Systems context for Educational Decision-making

The context for changing decision-making patterns in education based on Operations Research (Operations Analysis) and Information Systems is indicated in Exhibit 1. This concept has been propounded in detail elsewhere (1). Its major features are:

The computer has come into education, albeit haltingly and unevenly. Educational researchers can perform complex analyses quickly; for administrators, applications such as report cards, scheduling, and payroll can be performed readily, with more information stored and available than ever before.

Operations Research philosophy and methods, if not its precise techniques and formal models, provide an avenue for relating research and discipline-oriented data to school operating data and decisions. The intent is literally to improve the operation of schools by whatever means has the greatest promise of "payoff."

Personnel adequately trained to function according to this concept are scarce. The best source of people for new roles may be the educational researchers, who represent a near monopoly of quantitative ability and whose usefulness is being questioned. However, trained people may have trouble finding employment for many reasons, including present role perceptions in schools.

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1. Anderson, G.E.,Jr. Operations Research: A Missing Link. Educational Researcher, Vol. XXI, March, 1970. P. 1-3.

Many problems that are difficult to answer in a formal Operations Research context can be approached meaningfully in an Information Systems context.

Many examples of using existing computerized information processing techniques for more than the basic application they were designed for could be given. For instance, a school board negotiating with the teachers association has used a payroll program with a proposed salary scale (but without printing the checks) to determine just what that salary scale would cost, assuming personnel stability.

The most widely used example of this potential is school scheduling. When a computer is used, a school commonly makes one or two extra computer runs, usually to "clean up" the data so the final run will have a minimum of problems for hand resolution later. But if a school wishes to do so, it may use the same data and computer programs in a "simulation" mode many more times for purposes of refining the master schedule or trying out possible scheduling innovations. Inelegant, perhaps; relatively inexpensive; effective, for schools that learn to manage their own data and have some idea about what they want to do; and, by using this crude man-machine interaction method, each school doing so may decide on its own values at each step of the scheduling process.

Thus, it is not surprising that many of the "instances" to follow are really advanced applications of information systems technology to problems at hand. The ready availability of time-sharing computer terminals facilitates a man-machine interaction process that can be surprisingly effective despite its heuristic nature.

Our first example is a simple one: the management of a small Delphi exercise on a teletype time-sharing computer terminal (2).

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2. UMASS time-sharing system at the University of Massachusetts and General Electric Time-Sharing have been used for these examples.

Exhibits 2 and 3 show what happens on the first and second rounds, respectively (3). The computer is not doing anything that could not be done almost as quickly by pencil and paper methods, except possibly for the mailing time to distant points. In an instructional setting, aside from saving the teacher some paperwork, the students are learning not only the Delphi technique, but that a computer can be used readily and effectively for such tasks. The fact that the task itself is easily understood appears to build confidence in neophyte administrators.

The next example is a small budgeting model (4) whose main use may be that of forcing project and central office administrators to establish their priorities explicitly. By interacting with the computer terminal, it is possible to examine the results of various levels of funding and of changes of relative priorities very quickly in arriving at an actual budget. The steps in this procedure are as follows:

Each project manager defines for his project the desired money by line item (Exhibit 4a). Further, he defines more than one possible level of operation of the project, and the fraction of each line item budget request needed to operate at that level. In the example shown, Mr. Smith of the Instructional TV project (program) has requested $151,000 for his project to operate at its maximum intended level. However, level 1 operation can be maintained with 100% of the salaries, 50% of the equipment cost, 75% of the supplies cost, etc. 100% of the Supplies account is not used until level 4 operation is

3. This particular exercise was constructed and programmed by Mr. Thomas J. Murray, doctoral candidate in the School of Business Administration, University of Massachusetts, for a course in Decision-Making conducted by Dr. Kenan E. Sahin.

4. Mr. James C. Green of General Learning Corporation first developed this technique and the associated computer programs for the Model School Division of the Washington, D.C., Public Schools.

```
IS THIS YOUR FIRST ROUND FOR THIS EXPERIMENT?
ANSWER EITHER YES OR NO.
?
YES

WHAT IS YOUR NAME? (IT WILL BE KEPT CONFIDENTIAL.)
YOUR NAME MUST BE FROM 9 TO 16 CHARACTERS LONG
INCLUSIVE. USE BLANKS, IF NECESSARY.
?
G E ANDERSON

YOUR IDENTIFICATION NUMBER FOR THIS EXPERIMENT IS 2
PLEASE REMEMBER IT FOR FUTURE ROUNDS.

ALL QUESTIONS SHOULD BE ANSWERED ON A SCALE RANGING
FROM A LOW OF 1 TO A HIGH OF 10.
IF YOU WISH ADDITIONAL INFORMATION ON ANY QUESTION
ANSWER 99.

REPLACE TEACHER TENURE WITH TERM CONTRACTS.  1=STRONGLY DISAGREE
10=STRONGLY AGREE.


   WHAT IS YOUR RESPONSE FOR THIS ROUND?
99
THE CONTRACTS COULD BE FOR LONGER PERIODS AS A TEACHER GETS OLDER


    HAT IS YOUR RESPONSE FOR THIS ROUND?
?  W
2

DO YOU HAVE ANY COMMENTS TO SUPPORT YOUR RESPONSE?
ALL COMMENTS ARE ALLOWED THREE TELETYPE LINES. IF A
LINE IS NOT USED, ENTER A BLANK (SPACE), A COMMA, AND
CARRIAGE RETURN. DO NOT USE COMMAS OTHERWISE.
?
HARVARD REPORTS ITS GREAT ADVANCES TRADITIONALLY MADE BY
?
TENURED SECURE FACULTY WHO WILL BE AROUND TO LIVE WITH
?
THEIR WORK AND ITS CONSEQUENCES.

DISADVANTAGED STUDENTS SHOULD BE ADMITTED TO THIS UNIVERSITY UNDER
DIFFERENT CRITERIA THAN FOR OTHER STUDENTS


   WHAT IS YOUR RESPONSE FOR THIS ROUND?
?
7

DO YOU HAVE ANY COMMENTS TO SUPPORT YOUR RESPONSE?
?
NO
```

Exhibit 2: Round 1, Delphi

WHAT IS YOUR ID NUMBER?
?
2

ALL QUESTIONS SHOULD BE ANSWERED ON A SCALE RANGING
FROM A LOW OF 1 TO A HIGH OF 10.
IF YOU WISH COMMENTS FROM PREVIOUS ROUND ON ANY QUESTION
ANSWER 99.

REPLACE TEACHER TENURE WITH TERM CONTRACTS. 1=STRONGLY DISAGREE
10=STRONGLY AGREE.
THE RESULTS OF ROUND 1 FOR THIS QUESTION WERE
THE HIGH SCORE WAS 3
THE LOW SCORE WAS 2
THE MEAN SCORE WAS 2.5

WHAT IS YOUR RESPONSE FOR THIS ROUND?
?
99

HARVARD REPORTS ITS GREAT ADVANCES TRADITIONALLY MADE BY
TENURED SECURE FACULTY WHO WILL BE AROUND TO LIVE WITH
THEIR WORK AND ITS CONSEQUENCES.

WHAT IS YOUR RESPONSE FOR THIS ROUND?
?
2

DO YOU HAVE ANY COMMENTS TO SUPPORT YOUR RESPONSE?
NO

DISADVANTAGED STUDENTS SHOULD BE ADMITTED TO THIS UNIVERSITY UNDER
DIFFERENT CRITERIA THAN FOR OTHER STUDENTS
THE RESULTS OF ROUND 1 FOR THIS QUESTION WERE
THE HIGH SCORE WAS 7
THE LOW SCORE WAS 4
THE MEAN SCORE WAS 5.5

WHAT IS YOUR RESPONSE FOR THIS ROUND?
?
6

DO YOU HAVE ANY COMMENTS TO SUPPORT YOUR RESPONSE?
?
NO

Exhibit 3: Round 2 Delphi

reached.

The central office meanwhile is establishing its priority scheme (Exhibit 4b) for all the programs and projects. In effect, this is an ordered sequence for the allocation of money until either everything is funded or the available money runs out (usually the latter). This program ranking schedule indicates that 100% of the normal compensation increase will be budgeted, then 50% of the program to strengthen departmental administration, then 50% of the program to strengthen instructional services, then 40% of the funds requested for instructional television, then 40% of the funds for practical substitutes. If level 1 is fully funded and money remains, it will be assigned on level 2, to bring the program to strengthen departmental administration up to the 75% level, etc. Note that our Instructional Television project will not reach 100% funding until level 5 is reached centrally.

The computer (teletype time-sharing terminal, again) takes the data from project managers and the central administration, plus the authorized level of funds, and produces the report shown in Exhibit 5. This report shows us that the available money "ran out" at level 2 of the Strengthening Instructional Services program since the previous program is at the 75% level and the following program, Instructional Television, is at the 40% level. Further, we can see within program 4, Instructional Television, that the money allocated "ran out" on the Supplies line, which is at 43% of budget, not 75% as was requested for level 1 operation of that project.

Several "moves" are now possible:

- more money can be "found" somewhere to up the budget.
- cancel one or more projects and reallocate the money thus released.
- adjust the relative priorities of projects, either by reordering them in the Program Ranking Schedule or by increasing the fraction to be funded early in the process.

PROGRAM NAME: Instructional TV
DIRECTOR: Mr. Smith

PROGRAM COST PRIORITIES

Cost Object	Total Cost	Priorities (levels) 1	2	3	4	5
11-11 Salaries	9000	1.00				
21-17 Equipment	60000	.50	.75	1.00		
26-23 Supplies	50000	.75	.90	.95	1.00	
25-31 Prof. Fees	10000	.25	.50	.75	.90	1.00
25-94 Repairs, Mat.	10000	.25	.50	.75	.90	1.00
25-39 Contract Serv.	12000	.25	.50	.75	.90	1.00

Exhibit 4a: Within Project budget and priorities

PROGRAM RANKING SCHEDULES

Program	Priorities (levels) 1	2	3	4	5
Compensation Increase	1.00				
Strengthening Departmental Admin.	.50	.75	1.00		
Strengthening Instructional Svcs.	.50	.75	1.00		
Instructional Television	.40	.65	.80	.95	1.00
Practical Substitutes	.40	.65	.80	.95	1.00

Exhibit 4b: Between Project Priorities (Central Office)

FUND - CITY BUDGET
FISCAL PERIOD - 1971
AUTHORIZED LEVEL OF FUNDS 2600000
TOTAL COST REQUIREMENTS OF PROGRAMS 3193800

PROGRAM 1

OBJECT	REQUIREMENTS	ALLOCATED	PER CENT FUNDED
11	1480000	1480000	100
TOTAL	1480000	1480000	100

PROGRAM 2

OBJECT	REQUIREMENTS	ALLOCATED	PER CENT FUNDED
11	193500	160375	83
23	10000	5000	50
24	25000	12500	50
25	10000	5000	50
26	1000	500	50
29	10000	5000	50
31	5000	2500	50
TOTAL	254500	190875	75

PROGRAM 3

OBJECT	REQUIREMENTS	ALLOCATED	PER CENT FUNDED
11	725000	547205	75
31	70000	35000	50
25	27000	13500	50
26	250000	187500	75
21	20000	5000	25
23	40000	10000	25
TOTAL	1132000	798205	71

PROGRAM 4

OBJECT	REQUIREMENTS	ALLOCATED	PER CENT FUNDED
11	9000	9000	100
31	60000	30000	50
26	50000	21400	43
25	32000	0	0
TOTAL	151000	60400	40

PROGRAM 5

OBJECT	REQUIREMENTS	ALLOCATED	PER CENT FUNDED
11	148000	70520	48
21	15000	0	0
23	300	0	0
25	5000	0	0
26	8000	0	0
TOTAL	176300	70520	40

Exhibit 5: Allocation of available dollars according to established priorities

- adjust funds and priorities within projects to define a new level of operation.

All of this could be done by pencil, paper, and desk calculator, but it wouldn't be done soon enough to influence a meeting in progress. With the aid of the computer, it is possible to find out the effects of various proposed actions on a "while you wait" basis.

The next example is a school redistricting problem. The city in question had 3 high schools, 2 of them over capacity, with a very uneven distribution of non-white and non-academic students. The desired outcome was that students be better distributed among the high schools, in terms of total capacity and in terms of white-nonwhite and academic-nonacademic balances. If possible, it was desired to reduce the distances students had to travel to school.

Small areas within the city were defined, usually with the intent that all students within each small area would go to one particular school. School records gave an adequate indication of the number of students in each small area, and their racial and academic attributes. The school population in each small area was projected for 5 years based on the best available information, including potential urban renewal and changing racial composition of the city. Note that there is no demographic model in either approach used to suggest districting; population projections are input data.

This problem could be (and was) formulated as a linear programming problem (Exhibit 6) (5). Solution of the linear programming problem provided the "best that could be done" within the existing constraints. As suggested in the notes with Exhibit 6, some small areas were in fact split between high schools. Further, the students living across the

5. Mr. Robert T. Mall of General Learning Corporation was instrumental in running the linear programming solution to the problem.

School Districting Problem: Linear Programming Formulation

Let X_{ij} = number of students from area i assigned to school j

d_{ij} = distance from area i to school j

c_j = capacity of school j

s_i = number of students in area i

a_i = per cent of students in area i who are "academic"

$\overline{a}$ = city-wide per cent of students who are "academic"

n_i = per cent of students in area i who are "non-white"

$\overline{n}$ = city-wide per cent of students who are "non-white"

Then

Minimize $\sum\sum X_{ij}d^2_{ij}$ weighted squared distances

Subject to $\sum_i X_{ij} \leq c_j$ school capacity constraint

$\sum_j X_{ij} = s_i$ all students assigned somewhere

$\sum_i a_i X_{ij} \leq (\overline{a} + \epsilon)c_j$ academic balance

$\sum_i n_i X_{ij} \leq (\overline{n} + \epsilon)c_j$ non-white balance

where ϵ is an indicator of the amount of imbalance that can be tolerated.

Notes:

If $\sum_j c_j < \sum_i s_i$ no feasible solution exists.

It is difficult to require that X_{ij} be integer.

It is difficult to require that $X_{ij} = s_i$ or $X_{ij} = 0$. Some areas will be split between schools.

It is difficult to require that X_{ij} for school j be adjacent geographically.

Exhibit 6: Linear Programming formulation of School Districting Problem

street from one high school were assigned to another, which would be difficult to explain to the public.

The next approach, considering the need for a politically viable set of districts, was to develop a time-sharing program that would allow school officials to assign any small area to any high school they chose, and examine the consequences (6). Exhibit 7 shows a typical run of this computer program. Note that the program allows you to do several things:

- examine the consequences of the data as it now is.
- examine the data about student population forecasts and change any of it as desired.
- examine the assignment of small areas to schools and change any of these assignments.
- change all students in a small area to a new high school, or only the incoming freshmen. In the latter case, students already in a high school would not be moved.

As it turned out for this city, there simply was no redistricting plan that pleased very many people. The time-sharing computer program did allow the exploration of many alternatives, sometimes with various parent and community groups. The final decision was made where it probably belongs - in the political domain - but with the advantage of knowing probable consequences of several alternative plans and of reacting quickly to most new suggestions for redistricting.

The rapid growth of the concept of individualized instruction (open campus, independent study, open classroom, individually-prescribed instruction, etc.) and the concept of differentiated staffing (student tutors, teacher aides, etc.) have caused changes in the way schools operate, accompanied by problems that are amenable to analysis by simple Operations Research techniques.

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6. Mr. Robert T. Wall and Mr. James C. Green of General Learning Corporation created and used the original version of this computer program.

```
OLD FILE NAME--REDISTRICT
READY
RUN

REDISTRICT  22:38  2/12/70

IF YOU WANT INSTRUCTIONS, TYPE '1'.  OTHERWISE TYPE '0'? 1

THERE ARE 5 SPECIFIC ACTIONS YOU CAN ASK THE COMPUTER TO TAKE

   1. EVALUATE YOUR ALTERNATIVE
   2. FORECAST THE HIGH SCHOOL POPULATION FOR AN AREA
   3. TELL YOU WHICH SCHOOL THE AREAS ARE ASSIGNED TO
   4. CHANGE THE SCHOOL ASSIGNMENTS OF AREAS
   5. CHANGE THE FORECASTED HIGH SCHOOL POPULATION OF AN AREA

IN RESPONSE TO A QUESTION 'WHAT NEXT?' YOU TYPE A NUMBER
1,2,3,4,OR 5 TO INDICATE YOUR CHOICE.  THEN TYPE A COMMA
AND TWO MORE NUMBERS SEPARATED BY A COMMA.  DEPENDING
ON YOUR CHOICE, THE TWO NUMBERS MEAN THE FOLLOWING:

  CHOICE                    2ND NUMBER           3RD NUMBER

    1 - EVALUATION          YEAR E.G. '70'       # GRADES AFFECTED
    2 - FORECAST            AREA NUMBER          0
    3 - ASSIGNMENTS         AREA NUMBER(LOWER)   AREA NUMBER(UPPER)
    4 - CHANGE ASSIGNMENT   AREA NUMBER          SCHOOL NUMBER
    5 - CHANGE FORECAST     AREA NUMBER          YEAR

WHAT NEXT?  4,24,2     (Assigns Area 24 to school 2)

WHAT NEXT?  1,70,1     (Asks for effect if only 1 grade, new 9th, changed)

  P R O P O S E D   D I S T R I C T S   1970

SCHOOL          STUDENTS        PCT CAPACITY     PCT NONWHITE   ACADEMIC

FEENEY          1789             98              48.1           65.5
WILSON          2049            112.2            35             60.2
XAVIER          1388             86.7            40.3           60.9

TOTAL           5225             99.5            40.9           62.2

NUMBER OF GRADES AFFECTED = 1
PCT STUDENTS AFFECTED = 6.2
AVG MILES PER STUDENT = 1.17

WHAT NEXT? S
PROGRAM HALTED
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Exhibit 7: School Districting by Computer

For example, students are traditionally processed in classroom lots in education. In individualized situations, they may arrive in a relatively random manner for "servicing" at such facilities as a computer terminal, dial access terminal, study carrel, checkout of instructional materials, or even a teacher, counselor, or prescriber.

In planning for these new educational ideas and their settings, queueing can be a useful concept. It is usually infeasible to have so many student stations at each type of service facility that all students can be accomodated at any one time for non-group activities. Conversely, it is counter-productive to have so few facilities that students cannot make use of them when the educational philosophy of the school (the curriculum) says they should. Scarce resources tend to be tightly scheduled to assure maximum utilization; unless great care is taken, such scheduling tends to give each student a "time slice" rather than an "accomplishment slice" of the resource. (For example, drill and practice sessions in arithmetic at computer terminals in one large city are given to all students on the basis of 20 minutes twice a week, regardless of whether the student is so advanced he is beyond anything the machine has to offer or really needs much more time to gain the desired level of competence.)

One potential "solution" is to examine carefully the intended useage of each service facility in terms of how often and how long each time for how many students, and then perform an elementary queueing analysis to examine where the "trade-off" occurs between facility utilization and student waiting time. In some cases, it may be possible to make do with fewer of some kinds of service facilities. More often, it will not be possible to provide the proposed level of service with the number of service facilities available. Planners can then make decisions about providing more service facilities, scheduling them so they will receive maximum utilization, or taking steps to reduce the demand (fewer students, less frequent need, shorter contact).

Exhibit 8 shows an example of this kind of queueing analysis (7). From the best available data (which, admittedly, may be "shaky" data), it was estimated that a particular kind of student station would receive about 20 students per hour, that each would require about 10 minutes servicing on a one-to-one basis, 10 stations would be available, and one 9-hour day at a time would be considered. The queue program assumes a Poisson distribution of inter-arrival and of service times. It samples one day with the specified 10 service stations, another one day with 9 service stations, on down to a final one day sample with just 1 service station. Because of the randomization built into the computer program, it is desirable to run the program more than once with a given set of parameters, as indicated in Exhibit 8.

The results for this particular data indicate that if you have fewer than 4 service stations, the expected number of students cannot be served, but the facility utilization is very high. If you have more than 5 or 6, student waiting time is very short but facility utilization is low.

Typical of the use of such analyses as queueing was the attempt to operationalize the idea that every student should have free and easy access to his Counselor-Prescriber. If there is one such person for 250 students, crises will get attention, but non-crisis

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7. Worle, G.E., and Richards, T.C. Fort Lincoln New Town: Hand Simulation of Stage II of the First Facility. Unpublished report to General Learning Corporation, August, 1969. Every proposed student service facility was subjected to this kind of analysis. The computer program was created by Dr. Richards.

ARRIVAL RATE, STUDENTS PER HOUR= 20.00
SERVICE RATE, MINUTES PER STUDENT= 10.00
GROUP SIZE= 1.00
STARTING NUMBER OF SERVICE FACILITIES= 10
LENGTH OF DAY IN HOURS= 9.00
NUMBER OF DAYS IN SIMULATION= 1.00

NUMBER OF SERVICE FACILITIES	AVERAGE STUDENT WAITING TIME	AVERAGE FACILITY USEAGE	TOTAL NUMBER STUDENTS SERVICED
10	0	40.91	179.00
9	.03	38.52	195.00
8	0	33.50	156.00
7	.01	44.51	188.00
6	.23	50.35	165.00
5	.62	59.15	168.00
4	7.06	86.39	173.00
3	36.32	96.45	154.00
2	102.02	93.47	103.00
1	212.83	99.86	48.00

ARRIVAL RATE, STUDENTS PER HOUR= 20.00
SERVICE RATE, MINUTES PER STUDENT= 10.00
GROUP SIZE= 1.00
STARTING NUMBER OF SERVICE FACILITIES= 10
LENGTH OF DAY IN HOURS= 9.00
NUMBER OF DAYS IN SIMULATION= 1.00

NUMBER OF SERVICE FACILITIES	AVERAGE STUDENT WAITING TIME	AVERAGE FACILITY USEAGE	TOTAL NUMBER STUDENTS SERVICED
10	0	25.66	142.00
9	.01	40.19	180.00
8	.02	42.43	179.00
7	.01	45.66	174.00
6	.02	52.04	165.00
5	.07	49.32	151.00
4	11.97	90.46	177.00
3	13.87	82.55	139.00
2	114.80	97.95	108.00
1	201.58	99.10	48.00

Exhibit 8: Queueing Analysis

contact will either not occur regularly for large numbers of students or will be tightly scheduled some time in advance, either of which is contrary to the concept of free and easy access. Further thinking (translated as pressure from a "simulation" team for data) refined the concept of "free and easy access" to 2 3/4 student contacts per week of about 6 minutes each. Two Counselor-Prescriber types each available 5 hours a day, if utilized 100% of the time, could manage this amount of contact with 180 students. Queueing analysis indicated that 4 such people available half-time, but always interruptable (translate as 50% average facility utilization), would keep the student waiting time within reasonable limits. There are other assumptions and further considerations, such as that of interchangeability of "service facility" stations in the case of Counselor-Prescribers, and what do these people do that is interruptable the remaining 50% of their time. This problem will recur in the Adult Resources Flow Model.

One non-computerized simulation technique should be mentioned in connection with the design of the school for which queueing analysis was done. Through the simple expedient of creating a magnetic board representing the space to scale, with magnetic scale furniture and moveable partitions and firmly attached fixed scale walls, pillars, etc., it was possible to show interested people what the proposed space might look like. Going a step further, the creation of 180 short plastic rods and 7 long plastic rods, each with a piece of magnetic tape on one end, to represent students and adults the space was to accomodate, allowed exploration of just how proposed activities involving numbers of students and adults would fit into the space. If the space is set up as intended and only 160 of the 180 rods representing students will fit, some additional planning needs to be done. The 161st "student", for whom no activity space can be found, represents potential trouble in the real world.

The last "instance" is an additional technique for exploring the activities that should occur in a school being planned, adding the perceived roles of staff. The Adult Resources Flow Model takes as input the following: (Exhibit 9)

- The titles, numbers, cost, and hours of service for the entire staff, including all personnel used in any way for instruction.

- For each type of staff, the approximate per cent of time to be spent on each defined type of work. If upper and lower limits are specified, they are considered inviolable. If just one per cent for a type of work is specified, it is treated as a minimum. This input data results in hours available for types of work.

- For each type of work, the probable need for it based on the number of students, the number of faculty, occurrences per week, range of time for each occurrence, and type of distribution of time within the specified range:
  1 - Uniform distribution. Any length is as likely as any other length of time within the specified range.
  2 - Normal distribution. Times near the center of the range are more probable than either extreme.
  3 - Exponential decay distribution. Short times much more probable than middle or long times. (8)

The computer then samples the indicated work distributions the number of times needed to produce hours required (Exhibit 10) in a "sample" week. This may be matched against the hours available, and, where discrepancies exist, action taken to change job descriptions or the need for types of work.

Full details of the features of the Adult Resources Flow Model are beyond the scope of this paper (9). Several interesting

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8. Experience at the Oakleaf School, Baldwin-Whitehall School District, the pilot school for Individually Prescribed Instruction, indicates a need for constant conditioning of adults to make short, frequent contacts with students. The long contact must be the exception for the system to work.

9. Technical documentation and detailed operating instructions will be in a report to the U.S.Office of Education.

DATA FOR STAFF WORK, FLNT, 8-1-69
STUDENTS=700, FACULTY=35

	STAFF TYPE	NUMBER	COST	TOTAL	REG HOURS	OVER TIME
1	TEACHER STAGE 2-4 LEVEL 2	2	14900.	29800.	40	0
2	TEACHER STAGE 1 LEVEL 2	1	14900.	14900.	40	0
3	TEACHER COORDINATING LEVEL 3	6	12500.	75000.	40	0
4	TEACHER NURSING LEVEL 3	1	12500.	12500.	40	0
5	TEACHER RESOURCE CENTER LEVEL 3	1	12500.	12500.	40	0
6	TEACHER GRAPHIC ARTS LEVEL 3	1	12500.	12500.	40	0
7	TEACHER SHOP LEVEL 3	1	12500.	12500.	40	0
8	TEACHER AV LEVEL 4	1	8850.	8850.	40	0
9	TEACHER MUSIC LEVEL 4	1	8850.	8850.	40	0
10	TEACHER PHYS ED LEVEL 4	2	8850.	17700.	40	0
11	TEACHER LEVEL 4	6	8850.	53100.	40	0
12	TEACHER-AIDE	12	5700.	68400.	40	0
13	STUDENT HELPER - TUTOR	50	300.	15000.	10	0
	TOTALS	85		341600.	1900	0

HOURS AVAILABLE FOR TYPES OF WORK

	TYPE OF WORK	REGHRS	OVHRS	EXREGH	EXOVHR	MAXHRS
1	COUNSELING, PRESCRIBING	184.0	0	0	0	184.0
2	PLANNING	74.0	0	108.0	0	182.0
3	TUTORING	372.2	0	0	0	372.2
4	GROUP INSTRUCTION	188.8	0	0	0	188.8
8	PARENTS & COMMUNITY	11.6	0	23.2	0	34.8
9	IN SERVICE TRAINING	70.0	0	0	0	70.0
10	TESTING	152.2	0	26.6	0	178.8
11	SCORING / RECORDING	111.0	0	10.0	0	121.0
12	MATERIALS PREPARATION	42.0	0	84.4	0	126.4
13	SUPPORTING DUTIES	86.0	0	98.0	0	184.0
14	DISCIPLINE	0	0	18.0	0	18.0
15	SUPERVISING ACADEMIC ACTIVITY	133.0	0	57.0	0	190.0
	TOTALS	1424.8	0	425.2	0	1850.0

WORK DESCRIPTORS

	WORK TYPE	DIST	RANGE	STU	FAC	CON	CHG
1	COUNSELING, PRESCRIBING	3	.1- .2	2.75	0	0	0
2	PLANNING	3	.5-1.0	0	5.00	0	.50
3	TUTORING	3	.1- .3	2.44	0	0	.50
4	GROUP INSTRUCTION	1	.4- .8	.10	0	0	.50
8	PARENTS & COMMUNITY	3	.1- .3	.10	1.00	0	3.00
9	IN SERVICE TRAINING	1	.4-1.0	0	5.00	0	0
10	TESTING	3	.4- .8	.40	.50	0	.30
11	SCORING / RECORDING	2	0- .1	1.00	0	0	.30
12	MATERIALS PREPARATION	3	.5-1.0	0	1.00	0	1.00
13	SUPPORTING DUTIES	3	.5-1.5	0	5.00	0	.50
14	DISCIPLINE	1	.1- .1	.20	4.00	0	0
15	SUPERVISING ACADEMIC ACTIVITY	1	.8-1.5	0	3.00	0	.50

Exhibit 9: Input data, Adult Resources Flow Model

DEMAND FOR WORK IN WEEK 1 STAFF WORK, FLNT, 8-1-69

WORK TYPE		OCCURS	HOURS
1	COUNSELING, PRESCRIBING	1925	245.4
2	PLANNING	175	104.0
3	TUTORING	1708	235.6
4	GROUP INSTRUCTION	70	43.2
8	PARENTS + COMMUNITY	105	13.8
9	IN SERVICE TRAINING	175	122.0
10	TESTING	297	154.2
11	SCORING / RECORDING	700	39.0
12	MATERIALS PREPARATION	35	24.8
13	SUPPORTING DUTIES	175	113.6
14	DISCIPLINE	280	28.0
15	SUPERVISING ACADEMIC ACTIVITY	105	118.8
	TOTAL		1242.7

DO YOU WANT A NEW WEEK?
?YES

DO YOU WANT A NEW PROFILE?
?NO

DEMAND FOR WORK IN WEEK 2 STAFF WORK, FLNT, 8-1-69

WORK TYPE		OCCURS	HOURS
1	COUNSELING, PRESCRIBING	1925	225.7
2	PLANNING	175	127.6
3	TUTORING	1708	230.8
4	GROUP INSTRUCTION	70	41.1
8	PARENTS + COMMUNITY	105	15.3
9	IN SERVICE TRAINING	175	121.3
10	TESTING	297	152.5
11	SCORING / RECORDING	700	37.0
12	MATERIALS PREPARATION	35	23.1
13	SUPPORTING DUTIES	175	105.3
14	DISCIPLINE	280	28.0
15	SUPERVISING ACADEMIC ACTIVITY	105	120.3
	TOTAL		1228.0

DO YOU WANT A NEW WEEK?
?NO

Exhibit 10: Results from Adule Resources Flow Model

observations can be made from the sample run presented in Exhibits 9 and 10 however:

- It is very easy to define much more work that needs to be done than there is staff time to accomplish that work. For the data presented to be at all "feasible," it was necessary to eliminate entirely work types 5, 6, and 7, and to drastically curtail staff attention to discipline problems.
- There is still insufficient staff time for counseling and prescribing, compared with the time hypothesized to be needed. This was ultimately resolved by allowing lower level staff members to spend time counseling and prescribing.
- Staff perception of amount of time they should spend in group instruction and of the amount of group instruction needed to carry out the intent of the school being planned are discrepant.

No claim is made that this model is particularly valid. Its usefulness might be summarized as follows:

- Planners have been forced to try to quantify some of the implications of their plans, and, thereby, be somewhat more precise and detailed in their thinking.
- Major discrepancies between work that should be done and staff time allocation have been pointed out for further analysis.

Consequently, this model is classified with the "heuristics" rather than with formal modeling work.

To help schools plan for individualized curricula, additional models have been created as part of the Model Elementary Teacher Education Program at the University of Massachusetts(10). The EDSIM family of computerized models attempts at various levels of sophistication to analyze a performance criterion oriented curriculum with the possibility of a student's passing a pre-test and needing no instruction, or needing one or more instructional alternatives before a post-test is passed. Probabilities associated with passing

10. For more information, see the Simulation Modeling section of A Feasibility Study on the Model Elementary Teacher Education Program (Phase II), Final Report, Contract No. OEC-0-9-310417-4040, University of Massachusetts. Available from Superintendent of Documents, U.S. Government Printing Office.

tests and selecting instructional alternatives, and various time and resource requirements of these instructional alternatives make up the input data. Output data includes time for students to complete hypothesized curricula under various circumstances, and level of resources required for reasonable student flows.

The EDSIM models represent serious model development work, and one of them has undergone extensive validation studies (11). They are beyond the scope of this paper except to indicate next steps beyond heuristics in the application of Operations Research thinking to planning of new educational experiences for students.

In summary, we have seen a series of instances of trial and error, quick and dirty, heuristic approaches to helping schools analyze various problems, each increasingly closer to the concepts of Operations Research. While better models are being created, tested, documented, and made widely available, and perhaps for a long time after that, heuristic approaches such as these offer a useful way to help school people gain insights into their problems of management and planning. We may be well advised to help bring about a greater understanding and use of these heuristic techniques. To quote Robert Hayes:

> "I believe that the greatest impact of the quantitative approach will not be in the area of problem solving, although it will have growing usefulness there. Its greatest impact will be on problem formulation: the way managers think about their problems - how they size them up, bring new insights to bear on them, relate

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11. Foley, W.W. <u>A Validation Study of a Computer Simulation Model for an Individualized Curriculum.</u> Ed.D. Thesis, University of Massachusetts, 1971. To be included in a report to the U.S. Office of Education.

> them to other problems, communicate with other people about them, and gather information for analyzing them. In this sense, the results that "quantitative people" have produced are beginning to contribute in a really significant way to the art of management." (12)

Little mention has been made of the problems of applying even simple heuristic techniques: lack of clear definition of goals, misunderstanding and mistrust on the part of school people, lack of good data, unwillingness to make decision processes explicit, and simple lack of technical skills to use such techniques, to name a few. These problems are part of the challenge in developing improved management and planning processes for education, the challenge we must accept if our efforts are to count in the long run.

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12. Renetzky, A., and Kaplan, P.A. Standard Education Almanac, 1969. Los Angeles: Academic Media, Inc., 1969. P. 108. (Quoted in Farmer, J. Why P.P.B.S. for Higher Education? Boulder: Western Interstate Commission for Higher Education, 1970. P. 21)