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Computer-Assisted Planning in the Public Sector

Robert A. Nielsen

Vincent R. LoCascio

Time-shared computer usage makes it possible for municipal departments to gain much of the flexibility that has characterized successful private business—

COMPUTER-ASSISTED PLANNING IN THE PUBLIC SECTOR

by Robert A. Nielsen and Vincent R. LoCascio

Peat, Marwick, Mitchell & Co.

OUR BELEAGUERED cities seem to be in trouble on every side today. With a shrinking tax base and rising expenses, they are in a position analogous to that of a company whose market is vanishing even while its workers' demands are rising. The company at least has some options; it can reason with its workers; it can let some go; it can move into new fields; it can, in the final analysis, go out of business while it still has some assets.

A municipality is far more restricted in what it can do. It can not go into a new field nor can it go out of business. Very often, because it's in the business of providing vital services, it can't even "reason" with its employees—its firemen, policemen, sanitation workers, teachers—as effectively as can a private company.

Clearly municipal departments must—under these conditions—be unrelenting in their quest for newer, innovative approaches to the efficient planning of resource utilization. We believe a partial solution—one that has already proved effective in industry as well as some areas of the public sector—is computer-assisted planning. More specifically, a simulation model that incorporates the current status of a department, and the environmental forces affecting the community which the institution serves can play a significant role in each of the major tasks of planning: 1) establishing objectives, 2) taking action to achieve objectives, and 3) evaluating the effectiveness of the courses of action taken. Before describing in detail the nature of such a model, we must first digress for a moment to define more concretely the general nature of the tool we have in mind.

Basically, a model is any symbolic representation of any real system or process which abstracts from that system its important aspects, thus simplifying it and making it easier to understand. A map is a good example of a model since it symbolically represents a real area. But it is a static model since it shows the system at only one point in time.

A simulation model such as we are proposing shows how a system changes over time. To do that a model must include not only the current state of the system, but also consider environmental and other forces, and show how they work to change the system over time. If we wanted to make our map a simula-

The simulation model we propose shows how a system changes over time

tion model, we would have to add all the influences that shape the geography – weather, earthquakes, meteors, population shifts, etc.—and then project symbolically, perhaps through the use of overlays, how the area will look five, ten, 50, or 100 years in the future. Some of these influences are controllable, others are not. But all of them will interact with the current state of circumstances to produce a different set of circumstances for each year into the future.

Viewed in this light, models are just as feasible for any metropolitan department—the fire department, the police department, social services, hospitals, health care, education, even the municipal government itself—as they have proved to be for industry and other private sector institutions. The types of problems are much the same, even though the scale may be vastly different. And one of the traditional problems plaguing municipal departments has been their monolithic character; their inability to respond quickly to changing situations. The computer-assisted planning model allows the administrator of each department to rapidly simulate different possible situations (even those which seem only remotely possible) and to experiment with different plans to meet each projected situation.

The need to experiment with many different solutions to a given problem as well as the desirability of achieving immediate responses to the questions "asked" of the model suggests that the model could be most useful when set up to operate in a time-sharing environment.

If desired, a time-sharing computer system can be used to allow the planners in the municipal department to achieve immediate interactions that enable them to employ the model to quickly simulate different situations.

Now let's consider how such computer-assisted planning might be used in a metropolitan police department.

A police department has certain basic responsibilities: to keep the peace, maintain law and order, to control crowds, to organize and expedite traffic. It is organized into small, paramilitary forces responsible for given geographic areas—precincts—within the municipality. It may have, depending on the size of the city, a mobile force, a reserve, capable of being deployed into any given area where there is trouble. It also has headquarters units specialized in various types of crime whose services may be called upon by any one of the local precincts when a particularly difficult crime occurs in its area. It is, thus, a hierarchy—with certain limited resources—personnel and money—and certain problems with which to deal.

The type of problems that must be met are: How much of our resources (men and money) must be assigned to Precinct A, a decaying area with a growing crime rate, if the population level declines to 80 per cent of its present size? For, paradoxically, fewer people in a poor area can increase the incidence of crime; the wisest choice may be to increase the precinct strength as population declines.

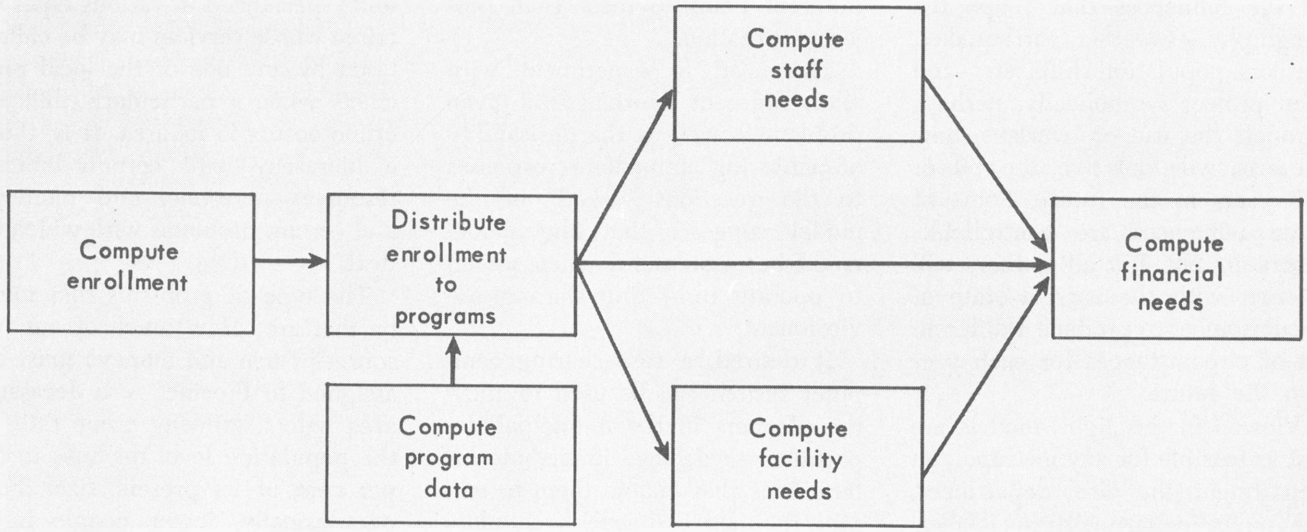
Would the area be best served by foot patrolmen or radio motor vehicles? What proportion of each?

What about Precinct B, a prosperous area of single family homes? There the crime rate is high, too, but it differs. Whereas A has a high proportion of muggings and crimes against the person, B's crimes tend to be more concentrated on burglaries and housebreaking—crimes against property. There an increase in total precinct strength might not

A police department has certain basic responsibilities, certain resources in men and money to meet those responsibilities.

Exhibit 1

Model framework



be necessary, but an increase in motor vehicle strength might very well be.

By providing answers to questions such as these, a computer-assisted planning model will permit senior officers to:

- Identify potential problems resulting from both primary and secondary effects of changes occurring within the metropolitan area.
- Test the impact of alternative decisions and environmental influences on the total resources that are or may become available to the department.
- Revise plans quickly to cope with unexpected developments.
- Develop contingent plans.
- Present the public—or in this case the city budgetary authority—with documented evidence supporting decisions.

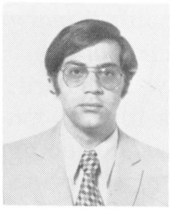
Since we have been advisers in instituting a model for several school districts within one county of a northern state, we will describe, as one example, the specific characteristics of this model. The reader is urged to bear in mind that this model is being used by a wide range of school districts, running from extremely affluent suburban areas to depressed manufacturing cities. Similar models for other municipal departments could likewise be structured to have the same flexibility and relevance to widely diverse areas in terms of size, economic factors, etc.

The framework of the model consists of a logic flow (illustrated in Exhibit 1 above) linking the five main "modules" or factual categories of an educational system: pupils, staff, programs, facilities, and finances. To identify educational system needs, the model incorporates quantitative data pertaining to these five categories. The data should be of a summary nature and detailed only to the extent required for significant planning decisions. Furthermore, the data should relate only to the most crucial planning considerations, and therefore exclude information that is only tangentially related to planning.

In broad terms, then, the types of information each of the modules should contain include the following:

- *Pupils* — Enrollment by school, grade, and program; average course load.
- *Programs* — Number of programs; number of sections; section sizes.
- *Staff* — Number of teachers by rank; number of paraprofessionals, and number of other employees; teacher workload.

ROBERT A. NIELSEN, CPA, is a manager in the New York office of Peat, Marwick, Mitchell & Co. He is a member of the New York State Association for Supervision and Curriculum Development and School Business Officials. His articles have appeared in this magazine and other professional publications. Mr. Nielsen received his bachelor's degree from Hofstra University.



VINCENT R. LoCASCIO is a management consultant in the New York office of Peat, Marwick, Mitchell & Co. Previously he was an operations research analyst with Eastman Dillon and a financial analyst with Johns Manville. He is a member of the Operations Research Society of America. Mr. LoCascio received his B.A. from Hunter College and his M.B.A. from New York University. His articles have appeared in **Financial Executive** and **Management Controls.**

• *Facilities* — Number of schools; number and size of teaching stations; operating hours per day; facility utilization.

• *Finances* — Salaries, supplies, and other expenditures by program; transportation cost; revenues.

The information on enrollment (by school and grade) and on average course load, combined with the information on the number of programs and desired section sizes, determines program enrollment and the number of sections offered by program. This, combined with current workload and facility policies, yields teacher and facility requirements. Given current resources, the model calculates additional staff needs and facility requirements, and then determines the total funds required to carry out the plan.

Each of these five modules consists of the same basic elements: *variables,* which are those elements of the model that vary over time (number of pupils, revenues, teacher pay scale, etc.) and are of three types—state variables, decision variables, and environmental variables; *relationships,* which show mathematically how changes in one variable produce changes in others; and *parameters,* which "tailor" the generalized variables and relationships to reflect the specific characteristics of a given district.

Variables

State variables reflect the state of affairs at a point in time of a resource or policy. Resource state variables indicate levels of resource usage such as the number of teachers, number of schools, and teacher station (classroom) utilization. Policy state variables, on the other hand, define the rules that govern the manner in which resources are used. Some examples of these are average pupil course load, teacher workload, desired section size, and number of periods per day. The model can also display summaries of state variables. For example, it can show number of teachers by school, by program, by rank, systemwide, and combinations of these.

Decision variables are used to effect a change in either resources or policies at a future point in time. Those decision variables that change resource levels (for example in the number of teachers or buildings) at a point in time are called ad hoc decisions. Such decisions are necessary to meet resource requirements.

Policy decisions have a broader effect than ad hoc decisions in that they change the resource requirements from what they would have been if no policy change were made. For example, a change in teachers' workload changes demand for teachers; a change in number of periods per day changes classroom utilization; a change in desired section sizes changes demand for teachers and classrooms.

To reflect the financial implications, the model automatically hires teachers to fill any gap between the number of teachers required for a program at a school and the number available based on the appropriate state and decision variables. These teachers are hired in the same mix (by rank) as currently exists for that program at that school. The user then has three options: accept this result; employ a different mix of teachers (by rank) to meet the requirement (ad hoc decision); or increase the teacher workload to change the teacher requirements (policy decision).

Normally the model's initial printout will incorporate no decisions. Then, at each point in the future where the model indicates resource requirements, the user will feed in his decisions. In fact, he may store in the computer a number of different sets of decisions that constitute plans for different contingencies.

Environmental variables are largely, if not entirely, beyond one's control, but still have an impact on the educational system. They include such items as rate of inflation, expected revenues from local sources, contractual obligations with teachers concerning workloads, section sizes, etc., and pupil survival rates from grade to grade. Like decision variables, environmental variables should be kept in a number of different sets to provide for contingencies.

A computer-assisted planning model will permit senior officers to:

• Identify potential problems resulting from both primary and secondary effects of changes occurring in the metropolitan area.

• Test the impact of alternative decisions and environmental influences on the total resources that are or may become available to the department.

• Develop contingent plans.

• Present the public—or in this case the city budgetary authority—with documented evidence supporting decisions.

EXHIBIT 2

ENROLLMENT PROJECTIONS

Since projections of enrollment levels influence the entire model, we utilized a rather complex and sophisticated methodology for calculating these levels. It incorporates 1 State (S), 10 Environmental (E), and 2 Decision (D) variables.

1. **Last year's enrollment. (S)**
2. **Transfer rates from school to school. (E) (Elementary to middle to high school.)**
3. **Academic attrition. (D)**
4. **Enrollment increase (decrease) from (non) public schools. (E)**
5. **Kindergarten enrollment. (E)**
6. **Pupil population effect of new homes. (E)**
7. **Pupil population effect of new apartments. (E)**
8. Pupil population effect of home resale. (E)
9. **Pupil population effect of apartment re-rents. (E)**
10. **Pupil population effect of vacant homes. (E)**
11. **Pupil population effect of vacant apartment units. (E)**
12. **Transfers to new schools. (D)**
13. **Pupil survival rates. (E)**

For each item 6-11 above there will actually be two environmental variables: one indicating the number of housing units involved, and the other indicating the pupil population effect per unit.

Let us look at what it takes to project enrollment for a middle school. In year 1, Hometown Middle School will have a given enrollment in grades 6, 7, and 8 (item 1 above). Step 1 is to promote 6th to 7th and 7th to 8th for year 2, and to draw new 6th graders from those elementary schools that "feed" Hometown school (item 2 above). Step 2 is to deduct academic attrition (item 3) from each grade and add it back to the figure for the grade below it. Step 3 is to adjust the figures for enrollment increases (decreases) from (non) public schools. Step 4 is to adjust the figures for items 6 through 11. Item 12 is used only when a new school is constructed during the planning period and it must be populated by drawing from the enrollment of one, some, or all of the other schools (of the same level) in the district.

Item 13, survival rates, is used as an alternative when the user wants to estimate the effects of items 6 through 11 without having to calculate each independently. Since these rates are nothing more than the ratio of this year's enrollment at each grade, divided by last year's enrollment at the grade immediately below it, they represent a simple alternative approach to enrollment projections.

The important thing is that no matter which of these methods is used, the model provides a capability in an area which, heretofore, has required very time-consuming manual computations.

Relationships

State, decision, and environmental variables so relate to each other that a change in one has primary and secondary effects on many of the others through a labyrinth of relationships. It is this mathematical connection of all the variables into an integrated system that makes the model truly a model rather than simply an assemblage of facts, and that permits the use of the model for planning purposes.

The model uses two basic types of relationships: those that project the future value of a state variable from a knowledge of its own current value and the decision and/or environmental variables acting upon it (intertemporal relationships); and those that calculate the value of one state variable from a knowledge of the values of other related state variables within a given year (intervariable relationships). One example of an intertemporal relationship is the projection of enrollment as described in Exhibit 2 on this page.

Other examples are:

Variable—Number of programs (1972). ***Relationship***—Number of programs (1971) plus change in number of programs (1972).

Variable—Number of substitute days per FTE teacher (1972). ***Relationship***—Number of substitute days per FTE teacher (1971) plus change in number of substitute days per FTE teacher (1972).

Variable—Substitute teacher pay scale (1972). ***Relationship***—Substitute teacher pay scale (1971) multiplied by per cent increase in substitute teacher pay scale (1972).

The model will project the future value for these and other state variables. Thereafter, intervariable relationships are used to calculate the value of the remaining state variables for each year in the planning period. For example:

Calculated value—Actual section size (school, course). ***Calculated from***—Enrollment (school, course), desired section size (school, course).

Calculated value—Number of sections (school, course). ***Calculated from***—Enrollment (school, course), actual section size (school, course).

Calculated value—Number of teachers required (school, program, rank). ***Calculated from***—Number of sections (school, program), sections taught per teacher per week (school, program, rank), current number of teachers (school, program, rank).

Calculated value—Teaching station utilization (school, type of facility, size category of facility). ***Calculated from*** — Number of teaching stations (school, type, size category), number of periods per day (school), number of section meetings (school, type, size category, time of day).

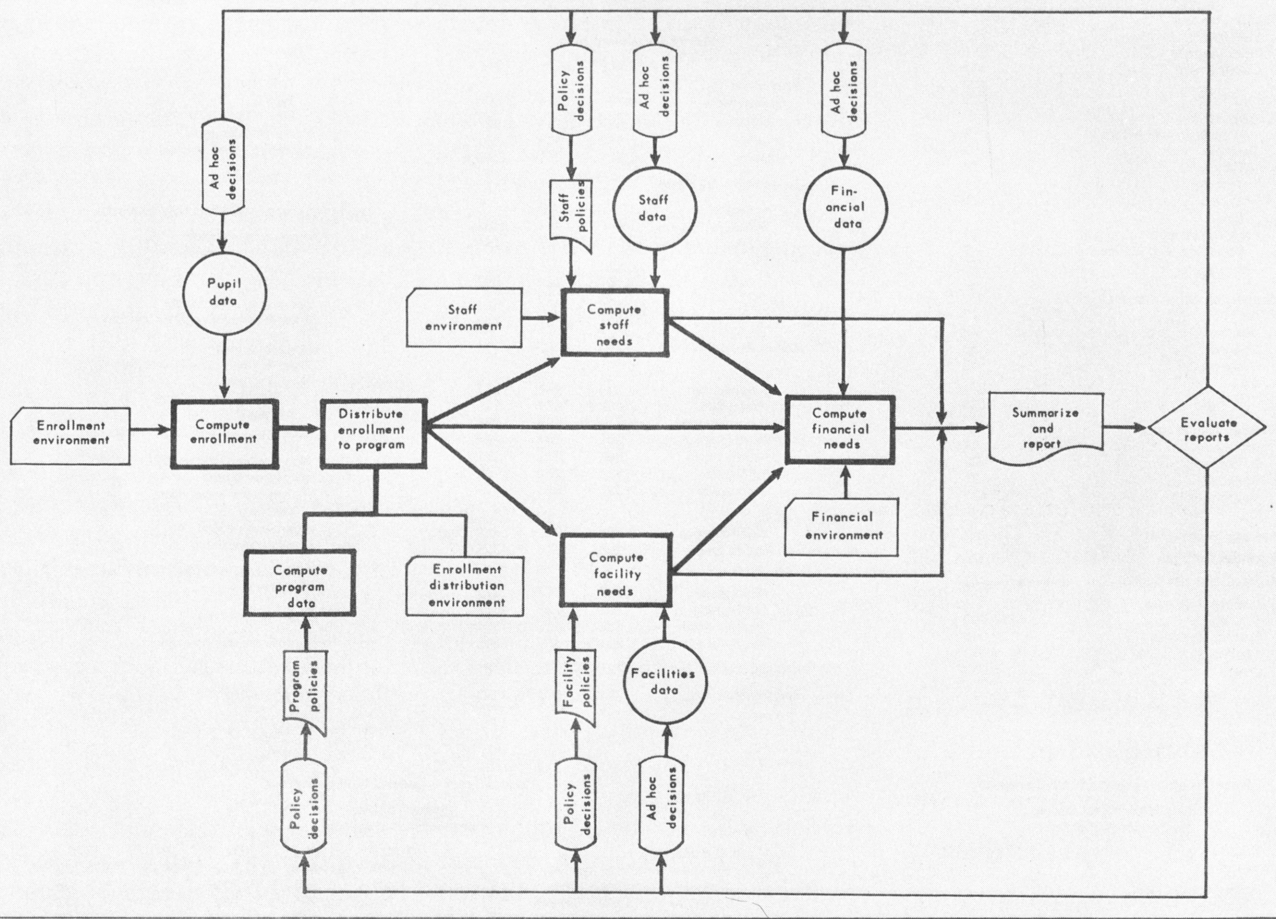
Parameters

Parameters "tailor" the generalized variables and relationships to reflect a school district's specific characteristics and information needs, and are of two types:

1—Parameters of the first type tailor variables by indicating the number of items in each breakdown category of each state variable. For example, *number of teachers* has three breakdown categories—school, program, and rank. To implement the model in two different districts, one would use these parameters to indicate that District A has, say, 10 schools, 27 programs, and 5 teacher ranks, and that District B has 8 schools, 30 programs, and 15 ranks. Only by using parameters in this way can two districts use the same generalized model.

2—The second type tailors relationships by identifying significant characteristics of categories, like school, program, and rank, that determine which items within a cate-

Exhibit 3
Logic flow of model



gory to include in calculating various relationships. For example, a district might use the first type of parameter to identify five teacher ranks, but, if the fifth rank were designated "paraprofessional," it would use a type 2 parameter to indicate that teachers of rank 5 are to be excluded in computing the pupil-teacher ratio (relationship). Type 2 parameters also designate:

- Whether a program is academic or extracurricular, thus determining, for example, which programs to include in projecting teacher requirements.
- Which programs require classroom space during the day (academic programs, study halls, etc.) and must therefore be part of the calculation of classroom utilization.
- Which schools are elementary, middle, and high, thus identifying which schools require course enrollment projections (high schools and perhaps middle schools, but generally not elementary schools).

How the model works

An expanded logic flow of the model (in which the nucleus of the system, previously shown as Exhibit 1, is accentuated by dark lines) is set forth in Exhibit 3 above. This exhibit identifies the building blocks that come into play at each of the processing stations, and shows that after the last year of the planning horizon, the model can generate a set of reports for the user to evaluate. The lines feeding back from the evaluation step are critical because they show how the user interacts with the model after analyzing the results of the previous run. Some of the arrows go back to make changes to ad hoc decisions while others go back to "change policies," reflecting the two basic types of decisions that can be made—ad hoc and policy. This interaction between man and machine is probably the single most important characteristic of a time-sharing computer model. Its instant feedback allows the user to experiment with, analyze, and revise alternative courses of action better and more quickly.

As an example of how the model works, let us look at the ABC school district which has just run its model and discovered that, given the decision and environmental variable sets used, the financial plan in Year 3 will require: obtaining an unprecedented 55 per cent of the town's revenues; or a 15 per cent increase in assessed valuation in the town; or a 15 per cent increase in the mill rate. After carefully analyz-

Exhibit 4

Illustrative reports

Middle school plan

	1972
Pupil enrollment	
Sixth grade	291
Seventh grade	311
Eighth grade	307
Total	909
Number of staff	
Principals/supervisors	3
Teachers	
Type A	14
Type B	21
Type C	15
Etc.	
Paraprofessionals	11
Secretarial and clerical	9
Total	73
Number of sections taught	
Art	15
Business	19
Science	33
Mathematics	38
Etc.	
Total	183
Average section size	
Art	17
Business	28
Science	25
Mathematics	23
Etc.	
Average teacher load	5.2
Pupil-teacher ratio	26
Average cost per pupil	$ 972
Instructional expense	
Salaries	$655,700
Material/supplies	22,000
Textbooks	9,000
Other	7,250
Total	$693,950

District enrollment plan

	1972	1973	1974
Enrollment			
System-wide	3,780	3,874	3,904
Elementary	1,987	1,989	1,997
Middle	592	634	661
High	1,201	1,251	1,246
Enrollment—By School			
Elementary			
School A	446	451	457
School B,	181	177	184
Etc.			
Total	1,987	1,989	1,997
Middle	592	634	661
High	1,201	1,251	1,246
Enrollment—By Grade			
Elementary			
Kindergarten	249	262	277
First grade	259	257	266
Second grade	278	268	259
Third grade	301	284	284
Fourth grade	281	311	291
Fifth grade	304	292	313
Sixth grade	315	315	307
Middle			
Seventh grade	294	321	332
Eighth grade	298	313	329
High			
Ninth grade	287	307	321
Tenth grade	301	294	316
Eleventh grade	332	311	301
Twelfth grade	281	339	308
Average cost per pupil	$1,121	$1,350	$1,481
Pupil-teacher ratio	24	25	27

District staffing plan

	1972
Number of staff	
Principals/supervisors	24
Teachers	
Type A	42
Type B	76
Type C,	38
Etc.	
Paraprofessionals	63
Secretarial and clerical	29
Total	272
Number of substitute days required	1,480
Average compensation	
Principals/supervisors	$16,980
Teachers	$10,169
Paraprofessionals	$ 6,280
Secretarial and clerical	$ 5,473
Substitute compensation per day	$ 40
Staffing work load	
Teaching load per FTE teacher (No. of sections)	
Principals/supervisors	2.1
Teachers	5.5
Teaching load per paraprofessional	3.1
Non-teaching load per FTE teacher (No. of sections)	
Principals/supervisors	5.9
Teachers	2.5
Non-teaching load per paraprofessional	4.7
After-school load per FTE teacher (In-hours)	1.7
Teacher-pupils ratio	21
Paraprofessional-pupil ratio	162
Sections taught	770
Average section size	27

Financial plan—general fund operations

Functional/object display
(in thousands of dollars)

	1972	1973
REVENUES:		
Revenues from local sources	$10,533	$11,586
Revenues from state sources	1,407	1,541
Revenues from federal sources	723	795
Other income	128	137
Total	$12,791	$14,059
EXPENDITURES:		
Central administration		
Personnel services	$ 324	$ 357
Supplies and equipment	97	104
Other	9	11
	430	472
Instruction		
Personnel services	7,593	8,376
Supplies and equipment	851	944
Library books	74	77
Other	97	109
	8,615	9,506
Health services	132	146
Attendance	47	51
Transportation	453	493
Food services	572	623
Operation and maintenance of plant	1,472	1,601
Facilities acquisition and improvement	672	692
Undistributed expense	71	88
Community services	87	89
Total	$12,551	$13,761
TRANSFERS TO:		
School lunch fund	$ 43	$ 46
Capital indebtedness fund	295	295
Total	$ 338	$ 341
Excess (deficit)	(98)	(43)
General fund balance	$ 221	$ 178

Financial plan—general fund operations

Program display
(in thousands of dollars)

	1972	1973	1974	1975	1976
REVENUES:					
Revenues from local sources	$10,533	$11,586	$12,892	$14,439	$15,788
Revenues from state sources	1,407	1,541	1,720	1,926	2,008
Revenues from federal sources	723	795	882	984	1,172
Other income	128	137	161	163	197
Total revenues	$12,791	$14,059	$15,655	$17,512	$19,165
EXPENDITURES:					
Instructional program					
Art	$ 390	$ 430	$ 481	$ 538	$ 597
Business	261	307	344	395	438
Science	1,042	1,150	1,201	1,355	1,501
Mathematics	1,206	1,329	1,471	1,647	1,791
Social studies	1,081	1,201	1,345	1,506	1,671
Physical education	521	640	717	803	891
Music	499	480	538	602	533
Foreign language	546	584	664	744	819
Reading	1,343	1,477	1,642	1,840	2,042
Industrial arts	233	275	310	334	371
Special education	172	189	212	237	259
Occupational education	105	117	141	201	262
Adult education	42	45	53	54	61
	7,441	8,224	9,119	10,256	11,236
Instructional support programs					
Guidance	278	306	342	383	425
Library	288	308	345	380	422
Health services	132	146	163	182	202
Research and evaluation	75	80	82	92	101
Attendance	47	51	54	59	64
	820	891	986	1,096	1,214
General support programs					
Central office management	320	350	390	426	472
School management	670	740	829	930	1,032
Transportation	463	511	572	640	701
Food services	572	623	692	775	832
Operation and maintenance of plant	1,506	1,641	1,801	2,017	2,188
Facilities acquisition and improvement	672	692	775	868	963
	4,203	4,557	5,059	5,656	6,188
Community services	87	89	102	113	131
Total expenditures	$12,551	$13,761	$15,266	$17,121	$18,769
TRANSFERS TO:					
School lunch fund	$ 43	$ 46	$ 49	$ 55	$ 61
Capital indebtedness fund	295	295	335	335	335
Total transfers	$ 338	$ 341	$ 384	$ 390	$ 396
Excess (deficit)	(98)	(43)	5	1	

ing the probable environment in Year 3, the administrator decides that there should be contingent plans for each of the following assumptions:

- Obtaining the historical 50 per cent of the town revenues, but with no increases in assessed valuation or mill rate.
- Obtaining 52 per cent of town revenues and a 5 per cent increase in assessed valuation.
- Obtaining 50 per cent of town revenues, a 10 per cent increase in the mill rate, and a 2 per cent decline in assessed valuation as a result of the XYZ chemical plant leaving the area. The plant's move will also reduce projected enrollment.

Neither of these alternatives will prevent a cutback in plans. However, to gauge the extent of the cutback, the administrator experiments with the model. First he lists the changes that could reduce the requirements for funds. For example, he could: Increase class size in all high school classes, except labs, by no more than 5 per cent; Agree to demands of a three-year, 20 per cent wage hike in the next year's teacher negotiations, but not their demands for reduced workloads from five to four sections per week; Begin a hiring policy for all elementary schools that aims at filling vacancies primarily with teachers directly out of college.

After a few hours of experimentation, the administrator develops a contingent plan for each of the assumptions by making the appropriate combination of changes. Specifically, if the district were to receive 50 per cent of the town budget and there were no increases in assessed valuation or mill rate (assumption 1), all three potential changes would be required; if assumption 2 were to be followed, the district could adopt a policy to reduce class sizes by 3 per cent and to hire slightly less experienced elementary school teachers; while for assumption 3 the most desirable solution would be to resist teacher demands for reduced workloads.

While this example, of course, does not fully illustrate the complexities of administering a school district, it does provide a simplified illustration of one type of problem that lends itself to computer modeling in a school district.

Besides financial analysis, the model is useful in analyzing construction decisions, teacher negotiations, and enrollment projections, to name just a few other areas. Each implementing district, moreover, has full flexibility to structure those output reports that will best reflect its own district's planning needs, and to structure the reports in whatever way best facilitates the types of analyses the district considers important. The reports illustrated in Exhibit 4, page 40, represent just some of the ways in which the model's data can be structured for use by school administrators and board members.

Conclusion

Any discussion of computer-assisted planning for use anywhere in the public sector should perhaps emphasize the word "assisted" in order to avoid any possible misunderstanding that quantification is intended to replace judgment. Indeed the model itself must reflect the administrator's own priorities and problems. Obviously the priorities and problems in a slum area will differ from those in a well-to-do neighborhood, whether for a hospital administrator, welfare director, or police director. Certainly no municipal process can be viewed as a system of mathematical equations. But by concentrating its efforts on the more quantifiable relationships and by avoiding the more subjective elements, the model will make it possible for the administrator himself to concentrate on program and student needs if an educator, on program and client needs if a social service director, on program and precinct needs if a police director. It thus frees the administrator from the burdensome task of making seemingly interminable calculations that are nevertheless necessary for effectively evaluating alternatives and making meaningful decisions in the public sector.

Any discussion of computer-assisted planning for use anywhere in the public sector should perhaps emphasize the word "assisted" in order to avoid any possible misunderstanding that quantification is intended to replace judgment. Indeed the model itself must reflect the administrator's own priorities and problems.