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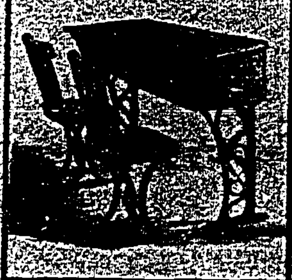
ABSTRACT

A computer-based version and a manual version of a set of techniques (EA008632-633) developed to assist in forecasting the need for primary and secondary school facilities and in critically evaluating proposals to satisfy that need are evaluated in this report. The report is organized into eight chapters. Chapter 1 summarizes the project organization, staffing, methodology, and final products. Chapter 2 reviews the general level of school facility planning in the United States, based on a survey of literature, school district interviews, and local and state questionnaires. Chapters 3 through 6 examine the four basic components of the system. Each chapter describes the techniques that have been developed during the project in light of the particular planning problem, and other relevant research activity. Chapter 7 summarizes different procedures for using the system, with emphasis on techniques for recognizing and appreciating "uncertainty." The final chapter summarizes initial responses to the system based on a preliminary evaluation by various school administrators. (Author/MLF)



School Facility Planning System

FINAL REPORT

prepared by

ST. LOUIS RESEARCH CONSORTIUM

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Preface

The School Facility Planning System has been developed to assist public school administrators in their planning for educational space. The System has been made possible by a grant from the National Science Foundation to a consortium of institutions in St. Louis, Missouri. A manual version and computer-based version have been developed and documented in separate reports. This final report reviews the research and development process, and the product that has resulted. The System has had relatively limited test experience. All users who identify deficiencies in the procedures or documentation are encouraged to notify the Executive Director of the Council of Educational Facility Planners, 29 West Woodruff Avenue, Columbus, Ohio, 43210; and/or the Director of Planning, St. Louis County Government Center, Clayton, Missouri, 63105.

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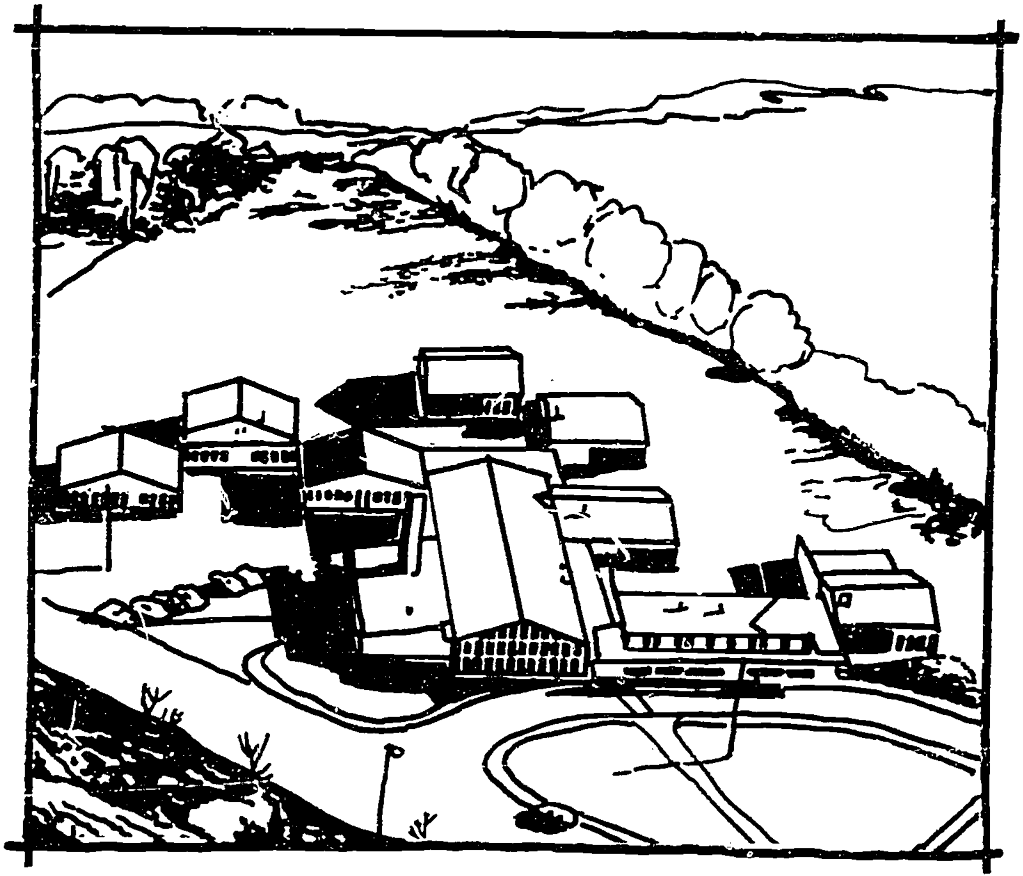

Chapter 1: Project Organization

The following report summarizes work carried out under the provisions of National Science Foundation Grant Number APR74-14195 to St. Louis County, Missouri. The research has been conducted in keeping with the general objectives of the program solicitation: To provide knowledge needed to improve the delivery of local government services, and to foster extensive utilization of validated alternatives among local governments.[1] More specifically, the project has focused on techniques whereby public school administrators might better conduct capital planning and budgeting under conditions of uncertainty. In this regard, it has concentrated on the following basic objective. "to evaluate and improve existing demand forecasting methods to increase their validity and usability for program administrators."

1.1 Introduction

This report describes the research project carried out by the St. Louis Research Consortium during the period June, 1974, through November, 1975. The report is organized into eight chapters. This chapter summarizes the project organization, staffing, methodology, and final products. Chapter 2 reviews the general level of school facility planning in the United States. based on a survey of literature, school district interviews, and local and state questionnaires. Chapters 3 through 6 examine the four basic components of the School Facility Planning System. Each chapter describes the techniques that have been developed during this project in light of the particular planning problem, and other relevant research activity Chapter 7 summarizes different procedures for using the System, with emphasis on techniques for recognizing and appreciating "uncertainty." The final chapter summarizes initial responses to the System based on a preliminary evaluation by various school administrators.

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[1] Program Solicitation NSF 73-27, Decision Related Research in the Field of Local Government Management (Closing date: January 24, 1974). The Grant was initially numbered GI-43109.

1.2 Product

The Consortium has produced a set of techniques for systematically planning future school buildings in an environment of uncertainty. In keeping with the general project direction, none of the basic techniques suggested are completely new. Rather, each builds upon already established analytical procedures. However, the refinement and assembly of these methods into a uniform package have not, to our knowledge, been accomplished heretofore.

Two sets of procedures have been developed and documented: one oriented to users with access to a computer, the other requiring only a hand calculator. Each approach has certain drawbacks. The manual approach will be laborious for most medium and large school districts. Alternatively, use of the computer version may require a longer organizational effort, especially when it is to be used on a non-IBM machine. Above all, neither version of the Facility Planning System replaces the user.

The School Facility Planning System is designed to test facility plans, not create them. It will not replace the data collection requirements, the judgement and the creativity that have traditionally gone into school planning. Therefore, to effectively use the System, the school district will be required to do considerable work. Historical information must be collected, educational standards and policies examined, and alternative solutions to a space problem devised. Given these reservations, the System does provide a structure and format in which to conduct school planning. It will enable the combination of intuitively derived standards and empirical information. It will speed up necessary calculations, permitting many "iterations" under different assumptions. It will help a district to appreciate the impact likely to result from alternative school policies or community conditions.

A pervading characteristic of the School Facility Planning System is flexibility. The user is presented with the ability to measure space requirements in terms of either teaching stations or square feet, depending upon preference. The ability is presented to conduct analysis at different levels of detail, on a district-wide basis, a school-by-school basis, or facility space type basis. Above all, the ability is provided to conduct impact analysis. Thus, schools may examine the probable effect of conditions over which they have no control, such as a shift in migration patterns or in the rate of assessed valuation growth. Similarly, they can examine the impact of changes in school policy or standards. Solutions of both a structural character (e.g., building or closing a school) and non-structural character (e.g., changing the desired students per classroom standard, sessions policy, or utilization rate) can be examined with equal ease.

1.3 Research Consortium

The School Facility Planning Project has been carried out by a group of St. Louis based organizations. The St. Louis County Department of Planning assumed lead responsibility for the project. Primary support was provided by the Intech Corporation, with additional assistance from the St. Louis University Center for Urban Programs, the St. Louis University Department of Education, and William B. Ittner, Inc.

In addition, considerable guidance was provided by a nineteen-member Project Review Committee. This Committee met on two occasions in St. Louis for purposes of reviewing methodology and specifying requirements. The Committee also reviewed intermediate products prepared by the Consortium. Staffed by a diversified mix of public school administrators, government and professional society officials, and private and university consultants, this group provided valuable advice throughout the project.

1.4 Study Phases

In keeping with the research proposal, the project was divided into eight separate phases. Invariably, there was some overlap between phases throughout the project. The basic purpose and accomplishments of each phase included the following:

Project Organization. During the first several months, an office was formed, contracts were initiated with all Consortium members and approved by the St. Louis County Council, and the staff was assembled.

Current Procedures Survey. In order to better understand the nature of the school facility planning process, several activities were initiated. Interviews were conducted with approximately twenty public school districts, varying in size, wealth, and facility problems. A literature search was initiated, concentrating on material listed in the Educational Resources Information Center (ERIC), Comprehensive Dissertation Index, the National Technical Information Service (NTIS), facility planning textbooks, and reports produced by professional organizations such as the Council of Educational Facility Planners and the

Educational Facilities Laboratory. Two questionnaires were designed to gather information from state departments of education and local educational authorities respectively. These questionnaires were examined by the Project Review Committee, reviewed by the Federal Office of Management and Budget, and distributed in February, 1975.

The culmination of Phase II was a working paper on the state-of-the-art in school planning, and a two-day meeting of the Project Review Committee in St. Louis. The document (Working Paper No. 1, 181 pages) examined typical school planning problems and procedures, and advanced techniques that have been tried in recent years. Using a combination of large sessions and workshops, the Project Review Committee suggested a tighter direction for the study and provided a series of research leads and desired systems requirements.

Systems Concept. The third phase of the study was that of developing an overview of the proposed system prior to the detailed design and development of any specific parts. This overview was drawn up in light of several guidelines which had evolved from the state-of-the-art survey and the Project Review Committee meeting. General requirements were that the system be:

> Open-ended; so that it could conduct both simple and sophisticated levels of analysis.
> Modular; so that it could be tailored to the particular study requirements of a given district.
> Flexible; so that it could be used by districts with different demographic patterns, legislative regulations, and school board policies.

From these deliberations, a rough system was designed consisting of seven basic components: enrollment, fiscal, existing facilities, educational standards and policies, present facility analysis, proposed facility analysis, and detailed facility analysis. The objective, general description scope, and detailed component descriptions were prepared in a second working document produced in December, 1974 (Working Paper No. 2, 98 pages). This document was distributed to all members of the Project Review Committee and served as the basis for all subsequent components.

Data Collection. Data collection activity, in fact, continued throughout much of the project. It was recognized that a school census would provide valuable data for projection purposes, as well as for more general planning experience. In this regard, members of the Department of Planning participated actively with a local school district in the design of an enumeration form, the preparation of collection procedures, the actual supervision of data collection, and the analysis. Additional effort was devoted to the collection of vacant land and structure information in selected St. Louis County districts.

Detailed Design and Development. The initial development efforts concentrated on the Enrollment, Facility, and Fiscal segments of the manual handbook. A draft handbook was distributed in March, 1975, to the Project Review Committee. The initial computer-based approach focused on a multiple regression program for projecting enrollments, and the use of a software package developed by Intech Inc., for the facility and fiscal analysis portions.

The Project Review Committee met again in April. Based upon their comments, selected techniques were revised, additional techniques were developed, and the format and style of the handbooks were revised. A revised draft of the manual version was distributed in June.

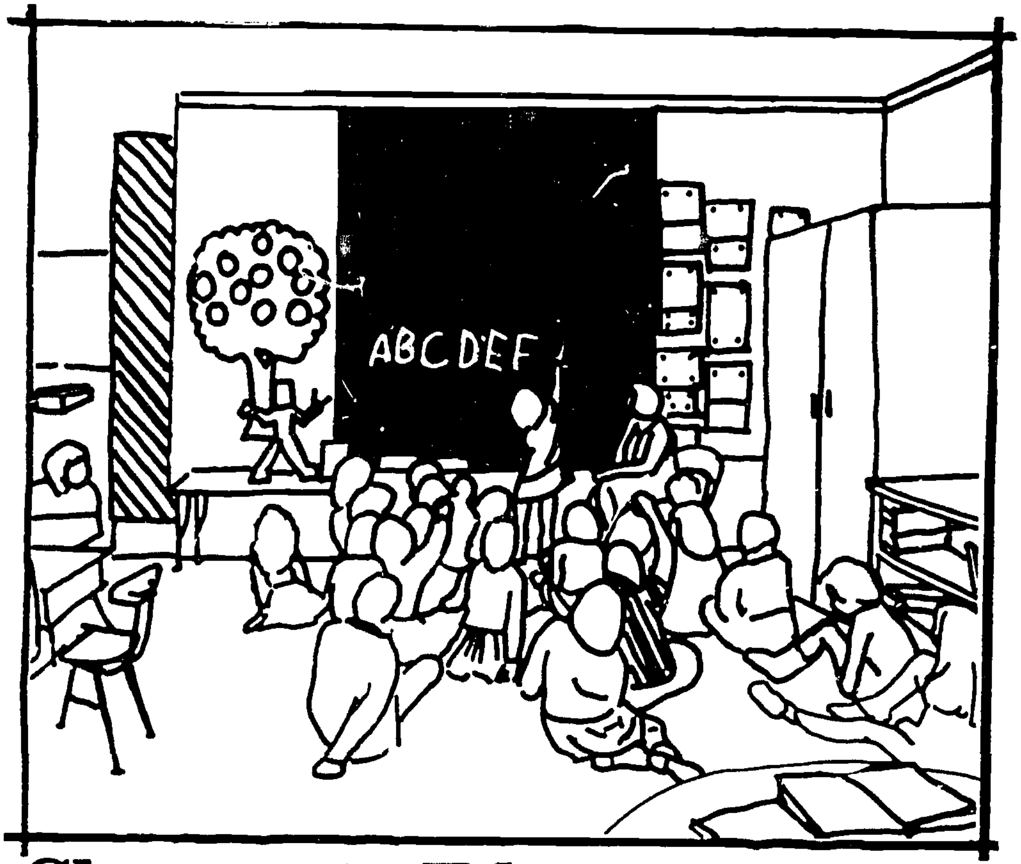
Testing and Evaluation. The original hope was that time and resources would permit extensive testing of the proposed system. Slippage in the design and development phase required that a less intensive evaluation effort be adopted. In this regard, the manual version of the handbook was distributed to Project Review Committee members, selected school districts across the country that had expressed interest in the project, and several additional school planning experts. These individuals and groups were requested to examine the document in light of an evaluation guide developed by the St. Louis University Department of Education. In addition to the written response to this guide, several seminars were held locally to discuss the System's capabilities. The computer version was tested on an IBM 370/145 in the St. Louis County Data Processing Division. The results of the evaluation phase have been summarized in Chapter 8 of this report. Many suggestions have also been incorporated into the final handbooks. Further testing of the System in many diverse school settings across the country is desirable.

Documentation. Documentation continued throughout the latter half of the project, involving many revisions. This effort was accomplished primarily by St. Louis County. Several local editors were retained. Five hundred copies of the User's Handbook: Manual Version were printed; in addition, several hundred copies of the User's Handbook: Computer Version and the final report were produced.

Project Conclusion. The last phase of the School Facility Planning Project consisted of a review by the National Science Foundation of all material, selected assistance to interested public school districts, and some publicity regarding the project. The grant specifically did not include a dissemination phase. While the St. Louis Consortium is interested in seeing that the System receives wide dissemination. the decision was made that an organization such as the Council of Education Facility Planners (CEFP) was best suited to support a large scale evaluation and dissemination effort. Accordingly, extra copies of all reports and programs have been forwarded to CEFP.

1.5 Summary

Those involved in facility planning research at the theoretical level will not discover any major conceptual advances in the School Facility Planning System. This is partly a result of the project's limited time and resources, partly a result of the difficulty of forecasting, and primarily a result of the project's overall focus. In keeping with the initial directives, we have prepared a practical, usable System that should help a variety of districts in their long-range capital planning and budgeting. The System is not easy; it requires time, data, and, above all, decisions on the part of the user. However, it should be considerably easier to implement than other facility planning systems, and when used judiciously should present equally accurate results.



Chapter 2: Educational Facility Planning

Capital planning and budgeting activity is characterized by certain common tasks and dangers, be it for private or public goods. As illustrated in Figure 2-1, the tasks may be thought of in terms of "transformations" which must be carried out by the planner.

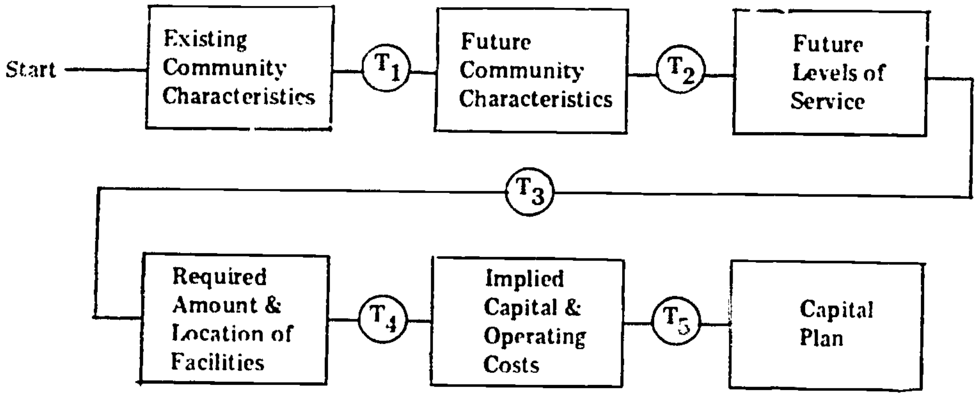


FIGURE 2–1 CAPITAL PLANNING TRANSFORMATIONS

2.1 Capital Planning Process

The capital planning activity begins with a review of existing supply and demand conditions. The demand for automobiles, golf balls, parks, public education, or any other commodity is examined in relation to the available facilities for supplying that commodity. The capital planner must consider potential gaps between demand and supply in the future, as well as the present. Therefore, the first transformation (T_1) requires a projection of future demand and supply conditions. The automobile manufacturer must project the future demand for cars and the future ability of existing plants to build them. The number, wealth, location, and tastes of individuals must be projected, as well as the probable deterioration and obsolescence of currently available factories. Because most future demand characteristics will depend upon factors that are beyond the control of the planner, they must be considered carefully, with attention to the probability of alternative futures.

The second step in the process requires that the future community characteristics be translated into their service requirements. The community must be analyzed in terms of its projected need and desire for specific goods. In the case of public goods, this second transformation (T_2) will require the establishment or identification of goals. Decisions must be made as to the desirable amount of open space refuse collection, or fire protection versus a lower tax bill. Every potential service level will imply a set of facilities, staff, and equipment necessary to provide it.

A comparison of the facilities necessary to meet future community goals with currently available facilities (which can be expected to deteriorate) reveals the extent of the planning problem. The third transformation (T_3) involves the identification of required facilities and the consideration of alternative plans that could satisfy this current and projected need. The problem has aspects both of quantity and geography. The number and the location of parks, clinics, or schools must be analyzed.

Every potential configuration of new facilities will have a price. Transformation four (T_1) "costs out" the fiscal implications of each proposal. The final transformation (T_5) requires that one of the alternative plans be selected, presumably that which comes closest to achieving the desired level of services within acceptable cost guidelines.

The actual capital planning process is, of course rarely as neat as the diagram in Figure 2-1. The outputs resulting from a given transformation will often cause a re-examination of the assumptions that led to that conclusion. A plan that appears too expensive (transformation 4) will cause the planner to consider alternative plans (transformation 3). However, the alternative plan options need not be limited to the consideration of smaller or cheaper facilities. Policies that would reduce required service levels during peak hours (transformation 2) may be feasible. Thus, a ban on lawn watering, an incentive for car pools, or an extra charge for electricity use in the evening hours may be reasonable alternatives to a larger water plant, highway, or generator. Similarly, the future community characteristics (transformation 1) need not be regarded as preordained. In recent years many suburban communities have discovered, through the use of zoning and subdivision regulations, the ease with which the number and kinds of people moving into a community may be controlled.

2.2 School Planning Process

For the most part, the capital planning and budgeting function for public schools may be conceived within the above framework. School planning in the United States takes many forms. With approximately 18,000 independent school districts across the country, it is understandable that much of the facility planning is characterized by unsophisticated methods and narrow scope. In some districts an intuitive, passive approach to school planning is adequate. However, as evidence accumulates of large-scale overbuilding of school facilities in recent years, the importance of more direct, rigorous long-range planning is clear. Of course, it is rarely clear as to whether the presence of a large excess or shortage of school facilities reflects poor planning or simply the complexity of the assignment.

A typical planning process for school facilities is outlined in Figure 2-2. The expected student enrollment must be forecast in light of the number and kind of people expected to live within the district. The future number of children within the district will, like most other demographic forecasts, reflect the combined effects of births, deaths, and migration. However, a more complicated aspect must be addressed: all school-age children do not attend the public school system. Depending upon wealth, religion, and other family characteristics, some proportion of the children will attend private or parochial school, repeat grades, or drop out.

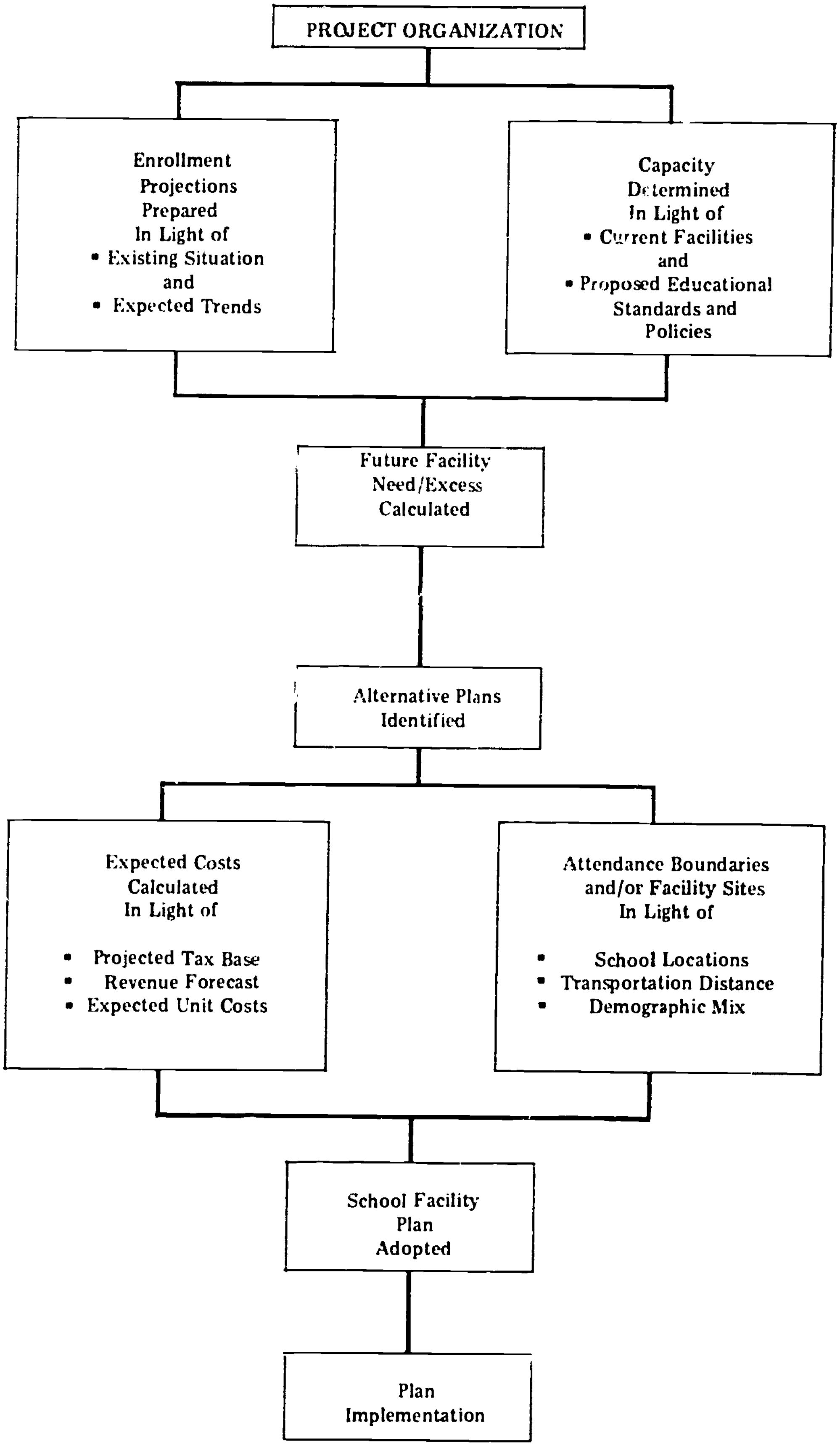


FIGURE 2–2 SCHOOL FACILITY PLANNING PROCESS

The service level implications associated with a projected student body will depend upon the educational goals of the community as expressed by school board and superintendent policy, and state legislation. The grade organization pupil-space and pupil-teacher ratios, curriculum offerings, recreational facilities, and transportation program are established either consciously or unconsciously. Each of these standards and policies must then be translated into its facility implications. Thus the decision to offer an automotive mechanics class, provide a hot lunch, have a football or tennis team, or allow students to drive to school will present a facility requirement which may or may not be possible within the existing facility capacity. A comparison of required facilities with the existing school plant will yield a measure of needed or excess space.

Numerous solutions will typically be feasible for resolving a space problem. Non-structural solutions in the form of grade reorganization, grade relocation, work-study programs, or an open school environment may be appropriate. Structural possibilities will include creating "found space" either within or outside existing facilities; converting unnecessary space to student, administrative, or community quarters; and, of course constructing or closing a school. Each of these facility solutions can be evaluated in terms of its direct operating and capital costs, as well as its educational benefits. Each may also be examined in terms of its geographic costs as measured in student travel time or distance, and/or student bussing expenses.

The consideration of alternative plans is usually an iterative process. In some instances, none of the alternatives will be found capable of meeting the desired educational goals and financial constraints, in which case additional alternatives must be formulated. In other cases, several alternatives may appear feasible. The trade-offs associated with each must then be evaluated, so that the optimal plan is selected.

Finally the plan must be implemented, a process that requires an additional set of designing, financing, scheduling, and monitoring tasks. The mechanics of obtaining voter approval for bonds, preparing site and structural designs, selecting a contractor and overseeing the construction, demolition or remodeling are not directly addressed as part of the School Facility Planning System.

2.3 The Evolution of School Planning Methods

School planning has in many respects paralleled urban and regional planning in the United States. There is little record of comprehensive school planning during the 19th century. A more fundamental battle for free public school education predominated much of this period. In the early twentieth century the planning movement became active again, splitting in two directions. One approach, the "city beautiful movement," emphasized the design and siting of public facilities; the second was more concerned with the reform of social and economic conditions. School planning experienced the twin pulls of concern for the building's visual, and to a lesser degree, functional qualities, and concern for the projected conditions and needs of the community. During the 1920s, a number of relatively comprehensive school plans were developed for major cities, and the concept of the school survey began.

"A school survey is the sine qua non of educational planning."[1] As developed principally by Nicholas Engelhardt, perhaps this century's foremost and most prolific American school planner, its purpose is to inventory the requirements, aspirations, and resources of a school district in order to formulate a long-range development plan. Many categories of school surveys have been identified including:[2]

The Community and Pupil Population Survey
The Finance Survey
The Educational Program Survey
The School Building Survey
The Expert School Survey
The Local Staff Survey
The Citizen Survey

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[1] Basil Castaldi, Creative Planning of Educational Facility (Chicago, Illinois: Rand McNally, 1969, p. 18.

[2] Ibid., p. 21.

The elements and procedures involved in carrying out these surveys have been refined over the last twenty-five years. Specific advances are discussed in the state-of-the-art sections of Chapters 3 through 6.

During the 1960s quantitative techniques began to find application in educational planning. Initial experimentation took place with computer-based regression, Monte Carlo, and linear programming models to forecast enrollment, establish attendance boundaries, and schedule classes and buses. Institutional advances occurred also with the creation of the Ford Foundation supported Educational Facilities Laboratory (EFL) in 1962 and the Council of Educational Facility Planners (CEFP) in 1965.

As the ability to conduct school planning has increased, so also has the complexity. The introduction of alternative schools, open campuses, modular scheduling, individualized student learning contracts, and other similar innovations has provided flexibility for students but additional variables for the school planner. Perhaps more than ever before, a good solution to a space planning problem in one school district will not be appropriate for the next district.

2.4 Local School Districts

In order to develop a system which would be useful to school districts, a concerted effort has been made to understand the typical planning techniques used by local districts, their problems, and suggestions for a planning system. A series of direct interviews was initiated with twenty school districts and a survey questionnaire was sent to a weighted random sample of five hundred local districts across the country. Both the interviews and the questionnaires covered the following aspects of school facility planning: enrollment forecasting methods, fiscal resource forecasting methods, evaluation of existing facilities, educational standards and policies, overall facility planning, computer capabilities, and additional suggestions.

The school districts for the questionnaire were chosen in the following manner: (1) school districts were divided into three enrollment categories: a) 1000-2,499. b) 2,500-4,999, and c) 5,000 and up; (2) total enrollment for each of these categories was calculated; (3) the sum of these enrollment figures was then calculated in order to determine the percent of the combined school enrollment that each group represented. The results were as follows:

Enrollment Category	Total Enrollment by Category	Percent of Total Enrollment
5000 and up	29,159,415	69.5
2500 — 4999	7,070,177	16.9
1000 — 2499	5,726,969	13.6

Therefore. 69.5 percent of 500, or 347 questionnaires, were sent to school districts having enrollment of 5000 and up; 16.9 percent of 500, or 84 questionnaires, were sent to school districts having enrollments of 2.500-4,999; and 13.6 percent or 69 questionnaires were sent to districts having enrollments of 1,000-2,499. The school districts within each enrollment category were chosen randomly. Approximately twenty additional questionnaires were distributed to specific districts known to have unique or highly developed planning procedures. Their returns were analyzed separately from the random sample. The districts chosen for local interviews were purposely varied in size and problems, and located primarily in the St. Louis area.

Ninety questionnaires were returned giving an 18 percent overall rate of return for the random sample. School districts with enrollments of 1000-2,499 accounted for approximately 13 percent of the returns; 17.6 percent were returned by districts having 2,500-4,999 enrolled; and the remaining 69.4 percent were returned by districts having 5,000 or more enrolled. The germane information extracted from the questionnares and interviews may be summarized with respect to forecasting experience, and all other planning considerations.

2.4.1 Forecasting

Professional judgement was identified by more responding districts, of every size, than any other method of forecasting enrollment or fiscal resources. Of those responding, 68.9 percent used professional judgement to forecast enrollment, and 61.1 percent used it to forecast fiscal needs. Response to other enrollment forecasting techniques were: cohort survival (56.7%), percentage change in enrollment (38.9%), linear projection (32.2%), absolute change (14.4%), and multiple regression (6.7%). Responses to techniques other than professional judgement for fiscal forecastings were: percentage change (38.9%), a source outside the district administration (31.1%), absolute change (28.9%), linear projection (15.6%), and multiple regression (3.3%). No enrollment projection was made or used by two percent of the respondents, while ten percent did not engage in fiscal projections.

The factors considered important in forecasting differed only in number among all sizes of school districts and all methods of forecasting. The following factors were considered important by survey participants in forecasting enrollment: (1) previous enrollment trends, (2) age distribution of pre-school age children, (3) age distribution of school age children, (4) birth patterns, (5) dropout rates, and to a lesser degree, (6) number of housing starts, (7) mobility, and (8) housing trends. Alternatively, the number of bedrooms per dwelling unit, age distribution of heads of household, religious composition, and median family income were not considered important factors in enrollment forecasting.

The factors considered important in fiscal forecasting followed a similar pattern. The variables considered important were (1) tax on real property, (2) assessed valuation, (3) state policy toward school financing (especially capital expenditures), (4) bonded indebtedness/bonding capacity, (5) legal or political considerations, (6) interest rates, and (7) voter attitudes. Among the factors considered least important in fiscal forecasting are the number of housing starts, interest rates, and trends in commercial and residential development.

The number of years districts project enrollment and fiscal resources did not vary significantly with regard to the district's size or forecasting method used. A large majority of survey respondents (77.9%) forecast enrollment five years or less into the future, while 22.1 percent use an enrollment planning horizon of six years or more. Of the participants which conduct fiscal projections, 93.7 percent project fiscal needs five years or less. The remainder (6.3%) forecast six years or more.

As might be expected, the percent error in a forecast and the number of years ago the forecast was made or updated were postively related. However, practically all districts reported three percent errors or less in their enrollment forecasts for the 1973-74 school year, with no variance in error attributable to anything other than the number of years ago the projection was made. In other words, there was no conclusive evidence suggesting that better results were obtained by those districts using sophisticated forecasting techniques as opposed to those using less rigorous methods. Fiscal resource forecasts were one percent wide of the mark or less for the 1973-74 school year projections, and again the accuracy was apparently attributable solely to the fact that most of the fiscal resource forecasts were made only one year into the future.

The search for sources of error in forecasting enrollments and fiscal resources was further pursued by examining the data used in the forecasting techniques. Comparison between districts to discover any different data sources was, however, essentially fruitless since the large majority of survey participants used their own enumeration or records of school-age children in enrollment forecasts, and state and local government agency data for fiscal resource forecasts. Moreover, neither the questionnaires nor the interviews provided a sound basis for evaluating the accuracy or uniformity of the data obtained from these sources.

Although no accountable source of error was revealed by comparing sources of data used by school districts, most districts stressed that the lack of data with which to measure and predict migration in their school districts constituted a primary forecasting problem. Problems encountered in projecting fiscal resources included the inability to predict state appropriations, tax base growth, and inflation.

2.4.2 Space Utilization and Planning

The remaining aspects of school facility planning covered in the questionnaire will be discussed in the following order: (1) the role educational standards and policies played in facility planning in each district, (2) how each district handled overcrowding or space under-utilization, (3) who was involved in planning in each district, (4) computer capabilities of each district, and (5) interest in a facility planning system.

The following educational standards and policies were listed by more than half of the districts as very important in facility planning: (1) total enrollment in each type of school (74.4%), (2) students per classroom (72.2%), (3) general system organization (71.1%), e.g., K-6, 3,3; K-8, 2,2, etc., (4) curriculum (67.8%), (5) student-teacher ratio (60.0%). Less than forty percent of the respondents felt that the number of graduates going to college, average transportation distance, sessions policy, racial balance, and community use were very important considerations.

A second aspect of facility planning focused on the way in which districts have faced situations involving overcrowding or under-utilization of space. The majority (65.1%) of the survey participants currently have some teaching space that is no longer used for instruction. Eighteen respondents (20%) have sold unused buildings. However, for the most part the excess space is evenly distributed between storage, office space, and special educational purposes. Many of the districts (70%) have experienced some overcrowding. In these cases, 35.6 percent of the districts used a staggered or double sessions policy, while 53.3 percent used temporary or portable structures.

The third aspect dealt with the number and variety of participants involved in the overall planning effort. With few exceptions central office administrators and school board members were identified as participating in planning all of the time, with teachers, local government planners, and outside consultants participating some of the time. This was true for all districts regardless of size or wealth. The estimated staff effort devoted to capital planning and budgeting varied widely with 54.3 percent of the respondents indicating less than nine person-months, and 14.3 percent reporting sixty months or more.

In terms of computer applications, approximately two-thirds of the respondents indicated that their districts have access to a computer. Predominant applications of the computer include payroll and bookkeeping activities (67.8%) and grade reporting (52.2%). Other applications are used by considerably fewer districts: fiscal forecasts and evaluations (22.2%), enrollment forecasts (20%), bus routing (14.4%), and facility planning (7.8%). Of those having access to a computer, forty percent would be interested in a computer-based planning system; twenty-six percent of those interested in such a system would consider spending more than $2,500 annually on it. Approximately one-third (36%) of the respondents indicated an interest in a manual planning system.

2.5 State Departments of Education

A second aspect of the current procedures survey focused on the role of the states in school planning. Forty-seven state departments of education (or equivalent) responded to a survey of state legislation concerning enumeration and fiscal requirements and technical-financial assistance.

2.5.1 Enumerations

Of the forty-seven states which responded, twenty-nine or sixty-two percent indicated that state law requires a periodic enumeration of school age population (generally ages one through nineteen). These surveys are conducted at various intervals ranging from once every ten years to an "on-going process." Of the twenty-nine states conducting enumerations, ninety-three percent conduct one at least every three years; seventy-six percent conduct an enumeration annually.

Information collected varies among the states. Indiana, for example, requires a comprehensive enumeration every year, on a district basis, including information on the total number of students by grade, means of transportation to school, number of students using the school food services, teacher/student ratio, racial composition, sex of population, and number of handicapped students. The state of Alabama demands an enumeration once every four years, acquiring such information as the number of students per school district between ages two and five and the number of families with incomes under $3,500. In some states, such as Delaware, state personnel actually conduct annual enrollment studies themselves, rather than relying on the local districts. The purpose of the state required data is primarily to provide a basis for allocating state funds.

2.5.2 Financial and Technical Assistance

Twenty-three or forty percent of the states responding allocate funds for capital planning purposes, either directly or indirectly. Ten of these states allow the expenditure of planning funds as part of the first phase of a construction project. For example, a percentage of the funds allocated for the construction or remodeling of a building could be directed to the planning and design of that facility. The State of Maryland finances all eligible and authorized capital construction proposed by local agencies. Capital planning costs are considered part of these construction costs.

Seven additional states devote funds for school capital improvement programs, which include general planning. This category differs from the above in that the planning funds are not tied to specific building or construction projects. For example, Illinois' Capital Assistance Program Guidelines state that one percent of appropriated funds shall be used for planning assistance. Planning funds are used primarily for analyzing needs, selecting alternatives, and/or developing preliminary design specifications for a project.

Other states engage more directly in planning for local districts. Kentucky establishes strict requirements for local districts at the state level. California, North Carolina, Utah, and New Mexico conduct planning studies for individual districts, but work primarily through the state offices, rather than funding the individual district. In all, thirty-three states claim to provide some form of technical assistance. Such assistance to the local school systems generally falls in one of three categories: (1) architectural, (2) engineering, and (3) consulting on financial, educational, or demographic issues.

2.5.3 Fiscal Legislation

State legislative considerations which impact school planning and budgeting from a fiscal perspective fall into two types: (1) financial limitations and (2) bond issue/tax rate approval. Thirty-four of the forty-seven states responding (72%) indicated that their districts are subject to a bonding limit, usually a percentage of the assessed valuation of the local district or county. As noted in figure 2-3, limitations on permitted indebtedness range from two percent in Indiana to forty percent of the assessed valuation in Nebraska.

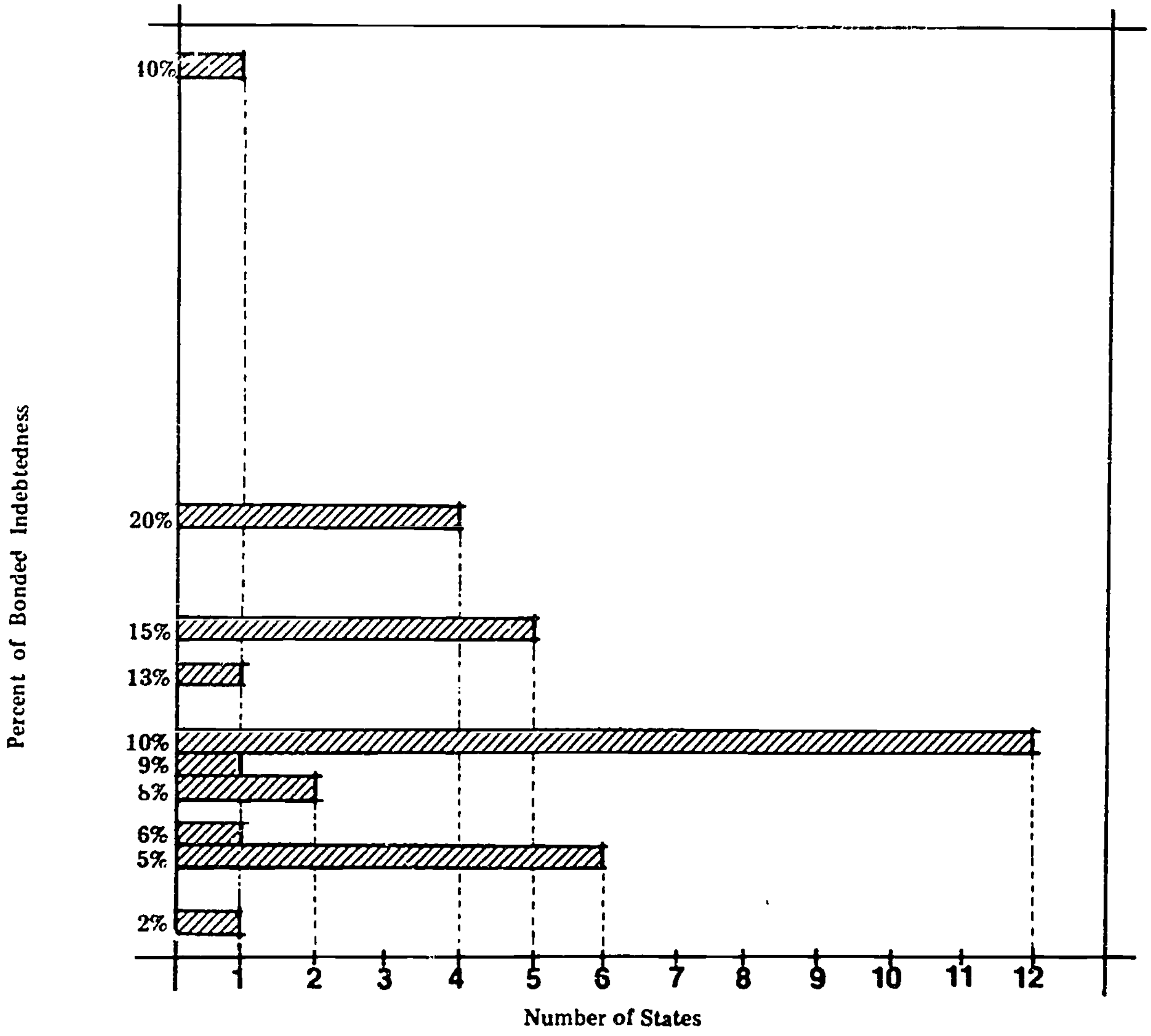
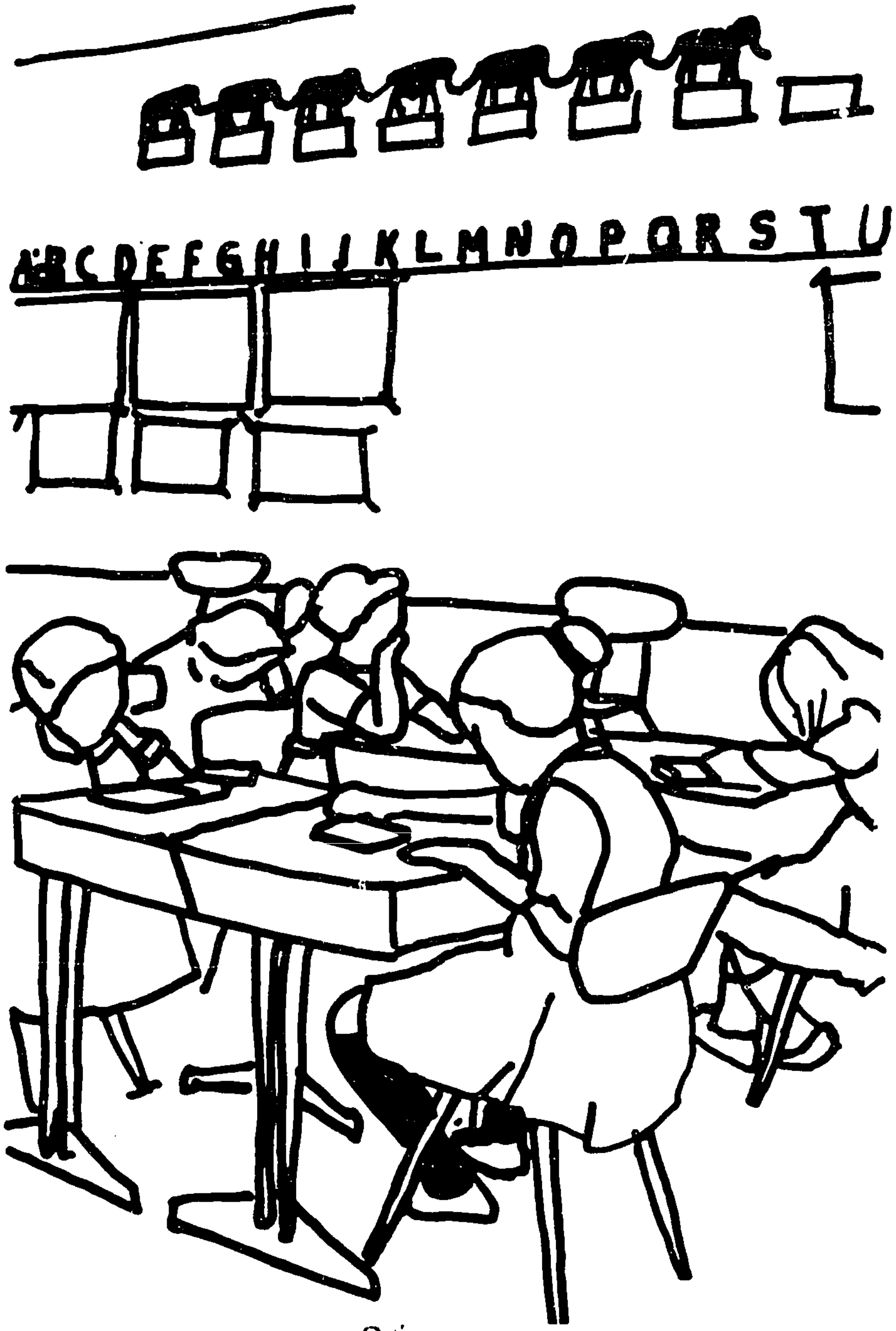


FIGURE 2—3 VARIATIONS IN PERMITTED BONDED INDEBTEDNESS AS A PERCENT OF SCHOOL DISTRICT ASSESSED VALUATION.

Other financial constraints include limits on interest rate payable on loans and bonds (five states) and time requirement/limitations to repay bonds or loans (three states). In eight states, the state will levy a special tax, of limited duration, for capital construction. This is generally done in combination with, or as an additional option to, established sources. Two states, Georgia and Vermont, will match funds with local districts.

In terms of public approval, thirty of the states require voter approval of a bond issue. Two additional states require a public hearing in the district or county before a bond issue can be approved. Nine states require that the state board of education give approval before a project or bond issue is submitted to the voters. Usually this approval is given only after an extensive survey of needs and conditions has been conducted by the state.

The role of state government obviously varies widely with respect to the planning of local district facilities. A surprising number of states have begun to get involved in the provision of technical and financial assistance This would seem to be a natural development. With the exception of the largest and most affluent districts, many local school systems will not have ready access to planning expertise unless it is provided by the state government.



Chapter 3: Enrollment Analysis

The primary purpose of school facility planning is to insure that school capacities will meet projected enrollments. Since adjustments to the school plant take time, years in the case of new facilities, planners cannot postpone school facility changes until actual enrollment changes occur. They must anticipate enrollment trends at least far enough in advance to allow time for required facility changes.

3.1 The Problem

If one hundred percent certainty existed as to the accuracy of enrollment forecasts, planners would know exactly when and where changes in facility demand would occur and with what magnitude, thus enabling them to focus full attention to effectuating the programs necessary to meet this demand. However, changes in a school district's enrollment are influenced by fluctuations in many factors, including size of the district's population, geographic and age distribution, quantity and types of housing, average family size, income levels, and birthrate. In turn, each of these has some influence on the others, and is itself influenced by similar factors that characterize the larger region in which the district is located.

A forecast of any one of these factors may be quite unreliable given the seemingly limitless number and combination of influences that could be exerted upon it during a given time period. Thus, it is clear that any enrollment forecast, plagued by the compounded uncertainty associated with the factors used in the model, must be considered with caution.

In addition to the problem of uncertainty is the problem of data collection. Too often forecasting models developed on a sound theoretical basis are thwarted in the testing stage because of the unavailability of data. For example, certain socio-economic and demographic data such as income levels, age distribution, or birth rates are rarely available for school districts, since school districts often have boundaries which do not coincide with census tracts, counties, or other jurisdictions for which this data is available. In light of this informational deficiency it might seem foolhardy even to attempt any enrollment forecasting.

However, the reality of "uncertainty" and limited data should not be overstated. Many of the factors influencing enrollment fluctuations such as age distribution, birth rate, and income levels change relatively slowly. This slow change introduces a stabilizing effect on enrollments. Other factors may fluctuate more rapidly but do so in a predictable manner, given historical data and reasonable assumptions as to the limits of change in a given district. Moreover, even though specific data by school district may not be available, data for jurisdictions which include the school district will often suffice. Where it is known that large differences exist between, say, county-wide age distribution and age distribution for a particular school district within that county, adjustments can be made to account for the difference.

In summary, although uncertainty in enrollment projections cannot be eliminated, forecasts may still be generated with some confidence to arrive at "ball-park" figures. The challenge is to produce reasonable forecasts upon which long-range capital decisions can be based, without necessarily initiating a major study or retaining an expensive consultant.

3.2 State of the Art

In the last decade, statisticians, planners, and educational specialists have proposed a number of procedures for enrollment forecasting, ranging from very mathematically sophisticated models to relatively straightforward adjustments of old procedures. At the moment it is unclear as to whether the more sophisticated models provide appreciably better results than the less sophisticated models. Most of the more sophisticated models have not yet been subjected to the kind of rigorous comparative testing which would establish that they provide results sufficiently better than some of the less elaborate techniques. When, and if, such comparisons are made or become known it will be possible to make more definitive judgments.

As part of the School Facility Planning Project it has been possible to review the various models and make some tentative judgments as to theoretical strengths and weaknesses, probable accuracy, and relative ease of application. More rigorous comparative testing has not been feasible within the scope of the project.

The following review of the literature follows the general classification system used by Wasik[1]. Forecasting methods are examined in one of three categories--extrapolation methods, structural flow methods, or Markov models. School district enumeration procedures are also reviewed.

3.2.1 Extrapolation Method

The vast majority of forecasting methods actually in use are extrapolation models of one sort or another. That is, they attempt to predict future enrollment on the basis of past trends in some relatively straightforward way.

3.2.1.1 Percentage of Survival

Without any question the most popular, at least in the sense of best propagated, method of forecasting is the percentage of survival technique, or, as it is variously known, the cohort survival method, the percentage of persistence method, and so on. Almost all the articles in non-technical education journals (e.g., American School Board Journal, School Management, School Executive, etc.) treat this method as the method for forecasting enrollment.[2,3]

The principle behind the cohort survival method is simple. Over time, a relatively consistent percentage of students pass from one grade to the next. After calculating that percentage for past years, it is a simple matter to multiply the number of students in any given grade by the percentage of survival which was established for previous years (five previous years being the most common). Thus, one obtains a forecast for the number of students who will be in the succeeding grade in the succeeding year. Using the same basic principle, one can predict the number of students who will remain in a cohort at each grade of their progress through the school system, once the cohort enters first grade.

Predicting the number of students who will enter first grade tends to be slightly more difficult, although that is obviously the crux of the issue for any but the shortest range forecasts. In general, the procedure is to apply the same basic principle, only instead of using the percentage of survival from one grade to the next, the planner estimates the number of first graders as a percentage of the number of births six years prior.

McNamara has suggested a relatively simple modification of this method for predicting first grade enrollments.[4] In most applications of this method, the ratio of prior births to first graders is calculated by determining the arithmetic average of the percentages for the five (or whatever) previous years. McNamara, however, borrows the process of recursive substitution from economics in order to derive weights for the survival ratios closer to the year for which the prediction is being made.

For instance, if a planner was attempting to estimate the first grade enrollment for some district as of 1976, he would not simply obtain the survival ratio by calculating the arithmetic mean of the survival percentages from 1968 to 1973. In McNamara's modification, the survival ratio for 1969 to 1973 would be most heavily weighted and remaining years would be very lightly weighted. This would tend to help account for pronounced recent changes in the percentage of births in a district compared to the number of first graders six years later.

McNamara claims this weighting procedure is more useful when the correlation between the prior birth rate and actual first grade enrollments diverges from $R = 1.0$. He cites one case where use of this formula decreased the error by one-third. This was admittedly, however, an unusual case as the correlation between prior birth rate and first grade enrollment was $r = -.81$. He gives no indication that much improvement in prediction can be expected under more normal circumstances. Nor does he indicate whether the prediction obtained by this modified cohort survival method is better or worse than a prediction obtained by some other method. Still, the method is easily applied and requires no extra data collection.

The major problem with the cohort survival technique of estimating forecasts is that it is frequently wrong, particularly in longer range forecasts. As early as 1952, Larson and Strevell found that, while cohort survival methods made predictions that were within ten percent on a one to five year forecast, they became very unreliable thereafter.[5] A study of 242 school forecasts made by the cohort survival method by Greenwalt and Mitchell showed that on seven-year forecasts the cohort survival method was reliable within ten percent in fewer than 100 cases.[6] Webster and Denham also cast doubts on the accuracy of the cohort survival method.[7,8]

On the other hand, Banghorst cites an unpublished study by Impara to support his contention that a cohort survival method is reasonably accurate, that is, within five tenths percent for one year and roughly an additional five tenths percent for each successive year.[9] Studies such as this, particularly when combined with the continued popularity of the cohort survival method, provide evidence that the method must be good for most practical short-range purposes.

One step that may be used to improve the usefulness of the cohort survival technique is the consideration of confidence bands for the forecasts actually made. A method for estimating confidence intervals is advanced in an article by Braden, et.al.[10] They convert an approximation of survival rate variance into approximate confidence intervals. The presentation of all forecasts with confidence intervals encourages administrators to take a more cautious, and therefore more realistic, approach to enrollment forecasts.

In summary cohort survival models have been shown on several occasions to be only moderately accurate predictors of enrollment. Their continued use is most probably due to the fact that they are easily computed and need very little data. Other than attempting to forecast first grade enrollments, a school administrator should have all the needed data at hand. Such models apparently predict accurately enough to fulfill the modest short-run desires of most school administrators.

3.2.1.2 Dwelling Unit Multiplier

Most of the experts in enrollment forecasting stress that, at the very least, crude checks on the housing stock within a district are absolutely necessary to avoid serious errors. If, for instance, a school district has experienced a substantial residential development within the last year, it is unlikely that the impact of this will be accounted for in a cohort survival method of prediction. Greenwalt and Mitchell are only two of several researchers who have shown that the cohort survival method tends to underestimate population in rapidly growing communities.

It is imperative, then, that all forecasters have some knowledge of changes in housing within their forecasting area. This implies a certain amount of cooperation with local agencies regulating and recording building starts as well as with local realtors.

Jaffe has gone a step farther.[11] He suggests that it is possible to base an entire enrollment prediction on the number of dwelling units in the forecasting area. He contends this is a particularly useful short-run prediction method for communities undergoing substantial growth in the development of land space.

The general procedure for predicting enrollment on the basis of dwelling units involves: 1) taking a census of dwelling units in the forecasting area (or, in the case of a longer range forecast, a projection of the number of potential dwelling units in the area); 2) determining from past census data the number of persons per household; 3) converting those figures into the proper age distribution; and 4) converting the age distribution, on the basis of prior experience, into enrollment forecasts.

For this approach to be effective the planner must be aware of the life-cycle patterns in his district. As communities get old or undergo any marked demographic change (e.g., racial transition), both the population per household and the age distribution of the population are likely to undergo substantial changes. Post specifically points out that experience in eastern metropolitan areas has suggested there will be a natural decline in the population of an area, due primarily to deaths and children leaving home, if these are not offset by new housing starts. In fact, for the Philadelphia metropolitan area, he suggests a formula for estimating total population which assumes an eleven percent loss of population in an area over ten years if it is not offset by new housing starts.[12]

Appendix D of the Jaffe article adds one further caution:

> It is an open question whether there is any such thing as a purely local trend in the development of a small area's population. The population growth of small areas appears to depend not only on the growth of its own housing supply but also on the provision of housing in many, many other small areas.[13]

This illustrates another of the difficulties in small area population projections and tends to suggest that larger area population estimates might, in the long run, be more effective. Swanson and Lamitie argue persuasively that metropolitan level planning is more effective than single district planning, regardless of what model is used.[14]

It is also worth mentioning that there are some very sophisticated urban land use models which project, or at least allocate, dwelling units.[15,16] Unfortunately, these urban land use models are neither particularly accurate at the small geographic area level nor are they inexpensive to use.

The dwelling unit multiplier approach, despite basic theoretical soundness, is not common in forecasting school enrollment because it raises many questions of data collection. Unless a school district had some automatic connections with the zoning commission or the office of building permits, it would need continuous surveys to determine building starts. Even if the school district was getting data from such agencies, there is no guarantee it would be in a readily usable form. Finally, there would be difficulties selecting the locally appropriate multipliers unless there were some data for previous years. In many communities this method could be most fruitfully employed as a rough check on other methods of forecasting.

3.2.1.3 Regression Methods

Regression methods can use simple regression - based either on time or on prior enrollments—or they can use multiple regressions, employing any number of factors.

Denham makes a general argument for using multivariate approaches wherever possible, but there is an absence of definitive proof that multiple regression forecasts are any more accurate than simple regressions.[17] At this point, the observations of Charters seem applicable:

> Multiple regression procedures, using four or five alternative predictor variables, might seem to commend themselves to the forecasting problem, but they are of limited value except in a few circumstances. Considering that the forecaster prefers to base predictions on recent experience and thus, may have no more than ten data points on which to construct a regression formula, the addition of predictors soon exhausts his degrees of freedom [18]

He suggests, instead, several applications of simple models under different conditions to make alternative enrollment forecasts.

Carss has, in fact, employed a multiple regression model but the accuracy of his predictions, an average error of less than three percent on one-year predictions while adequate, was not overwhelming.[19] In addition, his regression model employed no factors other than the cohort enrollment for the four previous years. He apparently used each of these as an independent variable for predicting the size of the cohort one year in the future. Certainly, this approach runs great likelihood of error because of multicolinearity.

On the other hand, Webster presents what is probably the most impressive argument made for any forecasting technique in favor of a simple regression model.[20] His argument 1)undertakes a systematic comparison to some other method, 2) shows clear-cut superior results, and 3) offers a compelling theoretical reason as to why his model should be superior.

Webster's basic argument rests on the observation that, while it is always possible to establish a ratio of persistence, as in the cohort survival method, this ratio does not tell the forecaster anything about the correlation between the two variables, in this case, the grade which one is using as a baseline grade and the grade whose enrollment one is predicting. And while correlation does not indicate causality, it does establish directional trends.

Consequently, Webster uses a least square regression formula to develop thirteen equations, one for each of the transitions between grades (including kindergarten). The use of the least square technique to determine trends in the survival ratios over the previous five years, tends to account for the specific linear trends which might be developing rather than wiping those trends out by averaging the different ratios. As Webster says:

> By averaging ratios, the cohort survival method washes out year-to-year differences in variability, thus contributing to error in the projections. In the case of regression analysis, on the other hand, the same differences in variability merely lower the size of the correlation coefficients.[21]

To compare the regression technique with the cohort survival method, Webster made predictions for twenty-five Michigan school districts, all chosen from a sample stratified to insure sampling of districts with different growth rates. In 100 predictions (elementary and secondary levels, forecasts of five and eight years) the regression method yielded better results in seventy cases. Using a binomial test, the difference is significant at the .022 level.

Furthermore, the percentage of errors in the predictions was considerably smaller for regression forecasts than for cohort survival forecasts in those districts which were undergoing rapid change. The superiority of the regression technique was never quite as clear-cut in those districts experiencing relative stability.

Barring contrary evidence, it would seem that the regression technique is clearly superior to the cohort survival technique. Furthermore, as Webster points out, the practicality of this approach is not particularly in question as: 1) it does not require any additional data from the data needed to make a cohort survival projection; and 2) standard computer programs are available to make the least square projections required.

3.2.1.4 Ratio Method

Ratio techniques do not so much involve any particular mathematical technique—after all, both the cohort survival and dwelling unit multiplier methods employ ratios to arrive at their forecasts. In this context, ratio methods refer more to the practice of attempting to base long-range school forecasts on long-range population projections by either the Census Bureau or some state agency.

> The basic historical information is the proportion of the state's total which attends public schools in a specific local area. This portion is then projected and converted into estimated school enrollment by applying it to the projected state enrollment.[22]

The major problem, of course, is to determine the appropriate ratio between the school district and the larger forecasting area. Jaffe suggests two techniques which can help in this area—least square regression and triple exponential smoothing, a technique which weighs most recent years in trend smoothing. He then gives examples of how to apply each of these methods.[23]

In the first example, making twelve-year enrollment predictions for Maryland counties, Jaffe uses a least square regression technique to determine the proper ratio of each county's share of the total state enrollment for 1980—which is, in turn, based on Census population predictions. In this example, however, he does encounter some difficulty in that there are wide divergences among the predicted enrollments for each grade within some counties. He contends, logically enough, that one would expect enrollments in the successive grades to show a certain amount of continuity. These discrepancies occur from choosing inappropriate regression lines. In actual practice, it probably would have been worthwhile to recalculate the predictions, using different regression lines.

However, it is worth noting the general principle, that the amount of divergence between successive grades, or groups of grades in his actual example, provides a crude check on the usefulness of the estimate. If the divergence is very large, one has reason for suspecting the accuracy of the overall estimate. His example of a very large divergence comes from one of the counties in his example which is predicted to have .0144 of all the Maryland children enrolled in grades 1-4 in 1980, but .0065 of children in grades 4-8, and .0172 of children in grades 9-12. Given family patterns, it is unlikely that a district would have so many children in primary and secondary grades, but so few in middle grades.

Attempts to apply this linear regression formula in California counties, the second example, did not work very well. To assess the applicability of the method, Jaffe tests it on five previous years. He finds an average error in the predicted share of enrollment for the five-year projection of 22.8 percent. Using the triple exponential smoothing method, he reduces the error for the past five years to less than eight percent.

When he uses the triple exponential smoothing approach to project into the future, he finds, in this particular example, that the smallest smoothing constant gives the least divergence between clusters of grades, but he warns that this must be determined separately for each case.

The general methods which he uses for predicting enrollments in states and counties are also applicable to individual school districts by relating "the population of school age within the local district to the same age population in the county for three Census periods.... The population of school age in the county is then related to the same population in the state."[24]

However, he warns, echoing a general concern of virtually all the articles reviewed, that the smaller the area or the fewer the number of previous data points, the more difficult the projection is and the greater the likelihood of error. In the example Jaffe cites, for instance, he is able only to predict total enrollment will increase between two and twenty-one percent.

This basic technique can also be modified to make sub-area forecasts. The ratio of the pupils in the sub-area to the total district must be determined, then the total projections for the district are modified to give some estimate of the sub-area. Again, however, the degree of accuracy is likely to be limited. In general, it is extremely difficult to make accurate forecasts for small areas. In all probability, it makes more sense to concentrate on administrative methods for fluctuations within sub-districts than to attempt to forecast those fluctuations. After all, long-range commitments, like buildings, are going to depend infinitely more on the overall growth of an area than on the fluctuations of any particular small area. That, of course, is assuming all things are equal; if some secular trend in a sub-district area is making a relatively permanent change in the neighborhood - a new housing development or a racial change— that is important to know about.

Still another use for the general ratio technique is in adjusting various demographic variables, particularly the birth rate, when the boundaries of a school district are not coterminous with other administrative units. Again, the basic concept is simple: one adjusts the birth rate of the entire administrative unit by the percent of the administrative unit's population living within the school district. The results will only be approximate, but they will, in most cases, be sufficiently accurate.

The ratio technique provides useful approximations for situations which are not readily covered by other techniques--long-range forecasts, small area forecasts, and non-coterminous administrative units. As such, it is most profitably used in conjunction with various other methods. It is a relatively uncomplicated procedure, even with the adjustments suggested by Jaffe for long-range forecasting, and does not require either elaborate calculation or extensive data. It is a useful tool in the planner's arsenal of techniques, but by itself is not likely to provide the accuracy needed for most day-to-day school district operational forecasts.

3.2.2 Structural Flow Method

According to Wasik: "Structural flow models will be defined as models which quantify certain structural relationships among various factors in the system."[25] Most of the models of this sort which Wasik gives as examples were not designed for the explicit purpose of predicting enrollments in public school districts.

For instance, Bolt et al. developed a set of equations to describe the flow of students from doctorate programs into various scientific professions.[26] The equations, though limited to linear equations, seem to be more useful for simulating various policy decisions about science education. Still there is no obvious reason why someone could not develop a model like this related to enrollment forecasts. Yet, neither is there any clear reason why they should.

One model of this type for actually predicting school enrollment was developed by Denham. Two basic assumptions underlie her effort: 1) it is best to present results in a probabilistic format to avoid the misplaced concreteness which can result from a single figure estimate; and 2) multivariate analysis is to be preferred over single variable analysis if possible.

Following these assumptions, she developed a clever computer program which employs the Monte Carlo method to generate a series of probabilistic enrollment forecasts.

The first step was to create a simple mathematical model of projected enrollment which included estimates of a number of key factors, such as previous enrollments, previous migration patterns, previous patterns of transfers from non-public schools, previous retentions, and so forth. The general concept was to disaggregate all the factors which were aggregated into the one ratio in a pure cohort survival method.

She then used a Monte Carlo routine to simulate enrollments under certain circumstances. That is, in simple terms, she ran her basic model through the computer for 100 iterations, using random numbers to determine whether high, low, or expected projections, which were three standard deviations from the mean of a beta distribution, would be used to calculate the value of each component for that run of the equation. The accumulated results, then, were readily reduced to a probability projection of enrollment.

The basic drawback to Denham's procedure is that the results do not appear that much more accurate than the cohort survival method predictions with which she was comparing them. They are significantly better, in a statistical sense, than cohort survival projections only when comparing for all grades over all six years of her projections. Her results are generally, but not significantly, better over specific years and grades. If one uses a plus or minus ten percent of actual enrollment as a criterion, as used by Greenwalt and Mitchell, the experimental projections had only nine errors, while the cohort survival method had ten.

Further problems have to do with the internal assumptions of the model. For instance, it seems that the assumption to not use a skewed distribution for the high and low projections for each component contributed to the fact that forty percent of the enrollment predictions fell outside the five percent limits of confidence. It also happened that the model showed a considerable amount of "noise." It was impossible to reject the null hypothesis for different random starting numbers and for fifty percent of the values produced by different simulations.

The Denham model has been used as part of the enrollment simulation model (ENSIM) tested by the Santa Clara County Component of Project Simu-School.[27] Tests to date have not indicated that the extensive data preparation effort, relative to simpler techniques, is justified by superior forecasts.

Another technique currently under development by the Santa Clara County Component of Project Simu-School is ENSIM II, a population model based partly on an analysis of land use and partly on the identification of population migrational patterns.[28] This model makes its projections based on an in-depth assessment of household mobility. A special census must be conducted to determine what types of families have a propensity for moving and what kinds of houses certain types of families will occupy. This information is then compared with the decennial United States census data to identify demographic change on a block-by-block level. ENSIM II requires that all households, housing units, and neighborhoods in the district be classified by type according to a number of social and economic characteristics.When this process of classification has been completed, probability matrices are used to predict future conditions in the district. The model also requires assessor, land use, and health related data. While no conclusive evaluation has yet been made of this approach, its extensive data requirements and the use of only two data points (e.g., censuses) in identifying housing trends are reasons for concern. Nevertheless, ENSIM I and II represent some of the most innovative enrollment forecasting research currently in progress.

3.2.3 Markov Chains

Despite several recent suggestions of the viability of Markov chain models to forecast enrollments, there is at the moment no compelling rationale for choosing this method for this task. At the moment, it seems as if the primary applicability of Markov chains is in modeling existing educational systems, particularly higher educational institutions, with an eye toward simulation for policy making.[29,30,31]

The major problems with Markov chains center around the calculation and the application of the transitional probabilities. In the first place, since the transitional probabilities depend on individual data, it is very difficult to gather the data needed for application.[32] Secondly, even if some data is available, it will probably be difficult to determine "the probability transition matrix with any degree of accuracy because of the relatively short data chain (twenty entries at most)."[33]

Even Johnstone and Phillip, who actually attempted to apply a Markov chain process to predicting enrollment, despaired of using that process.[34] They found the necessity of holding transitional rates constant and the relative insensitivity to shifts in the transitional probabilities two severe limitations. To test the latter problem, they tried two runs with their model, one using the transitional probabilities which they first calculated, and one using deliberately absurd transitional probabilities. The difference between the two runs was not appreciable for a number of years. They also point out that there is absolutely no data which actually demonstrates that a Markov model has much to offer in solving the problems of enrollment forecasting.

Therefore, at least for the present, Markov chains do not appear to offer any particular advantages for enrollment forecasting. There is no information which allows an estimate as to how expensive they might be, but it is clear that the necessity of calculating individual transitional probabilities would create difficulties in data collection.

3.2.4 School Enumerations

A review of enrollment forecasting approaches must recognize the pervasiveness of the district census or enumeration. While varying in frequency and purpose from state to state, enumeration results are often used directly in making student forecasts, as well as being a source of data for specific projection techniques.

If the survey collects information regarding preschool children by age, and intent to attend either private or public school, inferences can be made as to the number of future kindergarten and first grade students. By itself, a school enumeration fails as a forecasting technique, of course, because it doesn't address the question of migration - pre-school children that will move to or away from the district by the time they are of public school age. Some enumeration questions provide insight into community migratory trends by determining how long the family has lived in the district, and if and when it intends to move. This information will suggest trends but will not, without further analysis, contribute to quantitative forecasts.

Three general enumeration techniques are most commonly used: (i) door-to-door (ii) mail, and (iii) school child take home. Each technique has advantages and disadvantages in terms of cost and effectiveness. While the most costly, the door-to-door enumeration is, in most cases, the most effective. A well organized door-to-door enumeration can be expected to have an eighty-five percent return rate from all households, including those with no children in the public school system. The major disadvantage is the cost of retaining workers to conduct the survey, and training and supervising this staff. This cost increases with the size of the district.

An alternative to the door-to-door technique involves enumeration by mail. While less costly, the technique usually has a much lower return rate, often only forty percent. It is generally not valid to assume that the remainder of the population possesses the same characteristics as those which responded; therefore, the return rate in most cases has to be increased through some follow-up telephone or home visit procedures. In addition, conducting an enumeration by mail depends upon the availability of an accurate listing of all households within the district. If such a list is available, the cost of a mail questionnaire will be quite low. However, where not available, the cost of developing such a list can be prohibitive.

Of the three techniques, having school children take home the questionnaire is by far the least costly. It will also probably have a fairly high return rate. The problem with this technique is, of course, that only one segment of the district's population is covered. Households with children in non-public schools, with only pre-school children, etc., are not included. Again reservations with regard to basing assumptions on only a small sample of the population apply.

In summary, the first enumeration approach would appear to be the most valuable as it provides the most accurate description of the entire population. However, it is the most costly. A planner must consider the trade-off between accuracy and cost. Enumeration results which reflect only part of the total population must be employed with a great deal of caution. Basing generalizations on such details could result in an equal or greater amount of error than generalizations made in the absence of any enumeration data.

3.3 The School Facility Planning System Approach

The School Facility Planning System approach to enrollment forecasting is to offer four alternative extrapolation methods, namely, the cohort survival, time series projection, ratio, and dwelling unit multiplier techniques. Based on the assumption that not all users of the System will have sufficient funds for a computer, or perhaps have the desire to use one, procedures for carrying out these enrollment forecasting techniques are presented in both a manual and a computer version. An additional capability to utilize multiple regression is offered in the computer version.

The approach is based on our findings that, in general, less complicated models requiring only the most readily available data have resulted in enrollment forecasting accuracy equal to or surpassing that of more sophisticated models. Four techniques are presented in recognition of the fact that some techniques will be better suited to one community than another. Our approach also reflects an unsatisfactory effort to develop and test a workable multiple regression technique. The concept of this model is described below. The software package developed to implement the technique has been included as an optional capability (Appendix D - User's Handbook: Computer Version) for those users with the interest and data to pursue such an approach.

School administrators and planners are encouraged to examine each of the techniques carefully to determine those that may be appropriate in a school system. It is further suggested that several techniques be utilized. Comparisons of several forecasts which have been independently derived using different techniques may provide valuable insights into future enrollment patterns. Quite similar forecasts would strengthen the basis for reliance on the enrollment figures generated. Very dissimilar forecasts may point to the source of the discrepancy and thus reduce the possiblity of relying on forecasts based on invalid assumptions. Each of the above forecasting techniques is summarized below. Potential users are referred to the two User's Handbooks.

3.3.1 Cohort Survival

The cohort survival technique is the most commonly used enrollment forecasting method. As noted in Section 3.2, it requires only historical enrollment data by grade, historical birth data, and birth projections, which are normally obtainable for an area at least as small as the county in which the specific school district is located.

This forecasting technique involves the calculation of a series of "survival rates" which reflect the proportion of students in a given grade and year expected to progress or "survive" to the next higher grade in the succeeding school year. These rates are calculated using the following equation:

$$SR_{i,\,i+1} = (E_{i+1,\,j+1})/E_{i,j}$$

where SR represents the survival rate from grades i to i+1, and $E_{i,j}$ represents the enrollment in grade i in school year j. Generally, from three to five years of historical survival rates are computed. Average survival rates for each pair of consecutive grades are computed and applied to current enrollments to derive forecasts for each grade. These average survival rates may be further applied to subsequent years over the planning horizon so that enrollment forecasts may be generated as far into the future as desired.

The use of the average previous survival rate in the generation of forecasts implicitly assumes that survival rates will remain unchanged into the future. Users are encouraged to calculate rates that assign most weight to recent years, using techniques such as that suggested by McNamara (see Section 3.2). Others may want to project future survival rates based on historical trends and judgment regarding the future. Any of the extrapolation techniques discussed below may be used to project future rates. These projected rates can then be used, albeit cautiously, in place of average historical rates.

The System does not present a system for statistically calculating confidence intervals to be used in conjunction with the enrollment projections. As explained in the introduction to each handbook, there is little theoretical basis to expect that historical or current confidence limits will exist in the future. It appears more beneficial to concentrate on the basic shape and direction of the projection, and to consider the impact of alternative assumptions. Moreover, discussion with agencies that have experimented with the use of confidence bands revealed that they were not especially popular because of the additional required effort, and the tendancy to disregard them.

3.3.2 Time Series Projections

A frequently used method of projecting total enrollment is simply to extrapolate the total enrollment trend which has been exhibited in the past. This may be done by statistically estimating the curve which appears to fit best historical observations. As concluded by Webster, and again Wasik, when used in conjunction with sound professional judgment, this technique represents a useful forecasting tool.

This technique requires that the user specify the general shape of the curve which is felt most likely to reflect the expected enrollment trend over the chosen planning period. This may be done by selecting a curve from among several linear and non-linear alternatives. The selection of a particular type of curve is more important in obtaining an accurate enrollment forecast than is the statistical estimation of that curve. For this reason the user must consider all potentially important factors prior to making this selection. Such factors would include expected birth rates, migration retentions, dropouts, deaths, public versus private school preferences, and future housing patterns. Although not explicitly considered, expectations regarding all these factors will influence future patterns of enrollment growth or decline and should be subjectively examined before specifying a particular curve type.

Once a specific curve has been chosen, the historical total enrollment data may be regressed against time to estimate statistically the exact configuration of this curve. The curve which has been thus fitted to the historical observations can then be used to derive future enrollment estimates. The only data required is historical total enrollment figures, and in some cases (depending on the type of curve chosen), an ultimate maximum or minimum level of total enrollment, the specification of which will again require careful judgment.

Since several of the curves are non-linear various data transformations may be necessary. These transformations will depend on the nature of the curve type which has been chosen.

Two fundamental parts are involved in the generation of enrollment forecasts using simple linear regression: 1) The selection of a curve which is thought to be the most reflective of the future trend in enrollments, and 2) the actual computations involved in the statistical estimation of future enrollments. Linear and logistics curves are presented in the manual version. In addition to these, exponential and Gompertz curves may be used in the computer version.

Prior to the selection of a particular curve, the user is instructed to graph the historical enrollment data. This will assist in the selection process by allowing a visual analysis of previous enrollment patterns. The least complicated enrollment pattern is one in which there is a constant rate of absolute change in enrollment. The graph of this phenomenon is a straight line.

If past enrollment trends do in fact exhibit straight line growth or decline, and if this pattern is expected to continue over the chosen planning horizon, then a simple linear relationship may be the appropriate projection curve to use.

A least squares fit of $Y=\alpha+Bt$, where Y=total enrollment and t=time, is then generated manually or by the computer. Future enrollments are projected from the resulting formula.

The user is cautioned, however, that the use of a straight line curve implies that the absolute rate of growth or decline will continue over the entire planning period. This may be a valid assumption, particularly where the rate of change is gradual or where the planning period is relatively short. However, in a school system with fixed geographic boundaries, enrollments are unlikely to increase or decrease without bounds. The straight line curve may, therefore, be appropriate in cases where expected growth over the chosen planning horizon does not approach the estimated upper limit of growth, or where the expected decline does not approach the expected lower limit.

It is expected that growth or decline limits are to be approached during the planning period and/or if non-linear enrollment change is anticipated, the user may choose any of the following non-linear curves:

1. Exponential curve. The exponential curve would be used when there has been a constant percentage change in the rate of growth or decline of enrollment in the past and this trend is expected to continue over the planning period. A least squares fit is generated for the equation $Y = \alpha^{Bt}$. The resulting formula is available to project enrollments in the computer version of the System.

2. Modified exponential curve. The modified exponential curve is similar to the exponential curve in concept and shape. This curve, however, will eventually reach a maximum or minimum. A least squares fit of $Y = \alpha + B^{ct}$ is made where c is determined by first differences and x and B are determined by linear least squares. It is available just in the computer version.

3. Modified exponential curve with asymptote. This curve has the same general shape and formulation as the modified exponential curve. This curve type would be used when the user wishes to specify the maximum (minimum) value that the dependent variable can have.

4. Logistics curve. The logistics curve usually assumes an "S" shape. It is based on two assumptions: there is an upper limit to the variable being projected and the rate of change in that variable decreases in direct proportion to that upper bound. A least squares fit is generated for the equation $\frac{1}{Y} = \alpha + B^{ct}$. Logistics curves are available for growth and decline situations in both the computer and the manual handbooks.

5. Logistics curve with asymptote. This curve has the same general shape as the logistics curve. It should be used when the user wishes to specify the maximum (minimum) value that the dependent variable can have. The transformation of the basic logistics equation in the manual version is as follows for a growth situation:

$$Y = K \; / \; 1 + e^{a + bt}$$

$$K/Y = 1 + e^{a + bt}$$

$$K/Y\text{-}1 = e^{a + bt}$$

$$\ln\left[(K/Y)-1\right] = (a + bt) \ln e$$

$$\ln (K/Y\text{-}1) = a + bt$$

where:
K is the anticipated maximum enrollment limit
Y is enrollment and
t is time.

Note that the Beta coefficient is less than zero; therefore, as time approaches infinity, the quantity K/Y-1 will approach zero. In the logistics decline situation, the same formula is used but it is shifted down by an amount M. In this situation the upper limit achieved by the historical data (which is known) is K-M, and the lower unit (which is estimated and supplied by the user) is 0. The equation then becomes:

$$\ln \left[\left\{ (K\text{-}M) \; / \; (Y\text{-}M) \right\} -1 \right] = \hat{a} + \hat{b}t$$

where:
M is the anticipated minimum enrollment limit and all other terms are the same. Note that in the decline situation the Beta coefficient is greater than zero, and the quantity K-M/Y-M approaches an infinitely large number over time, while Y approaches M.

6. Gompertz curve. The Gompertz curve is a special case of the general logistics curve. The rate of growth (decline) for this curve declines by a constant percentage each year; whereas the change in the regular logistics curve is in direct proportion to the limit. The equation for this curve is as follows: $\log Y = a + B^{ct}$. It is available only in the computer version.

7. Gompertz curve with asymptote. This curve has the same shape and formulation as the Gompertz curve and should be used when the user desires to specify the maximum (minimum) value the dependent variable can take.

In addition to extrapolating enrollment trends, these curves may be used for projection of survival rates in the cohort survival projecting technique, projections of ratios in the ratio technique, and for projections of dwelling unit multipliers. They are also useful in forecasting selected fiscal variables such as assessed valuation or average salaries and benefits.

3.3.3 The Ratio Technique

Another alternative enrollment forecasting technique is the ratio method. In it the forecasts of local school system enrollments are based upon projections of the population or enrollment for some larger geographic area. This larger area may consist of the county, Standard Metropolitan Statistical Area (SMSA), or even the state which contains the local school system and for which there are reliable population or enrollment forecasts available. It is assumed in the manual version that the relationship between school system enrollments and the population (or enrollment) of the larger area will remain constant, or that it will continue to change at the same rate as it has in the past. The computer version provides more flexibility in choosing the rate of change in the ratio of school system enrollments to the population (or enrollment) of the larger area. This greater flexibility is achieved through the use of non-linear extrapolation curves in addition to linear curves in the projection of the ratio.

The ratio method initially involves the calculation of the historical 'ratio' between local school system enrollment and the population (or enrollment) of the larger area. A typical ratio would be computed as follows:

$$R_t = L_t/A_t$$

where R_t is the ratio in time period t, L_t is the enrollment level in the local school system in year t, and A_t is the population (or enrollment) of the larger area, also in the year t.

Based upon historical values, this ratio may then be projected into the future. If no trend is discernable from the historical values of the ratios, then the average of these past ratios may be used as the forecast value of this variable. If, however, some trend is exhibited, it may be extrapolated into the future using professional judgment or a projection technique wherein the values of the ratio are regressed against time. The straight line extrapolation technique should be used only where the ratio changes gradually, and should be confined to a planning horizon which includes only those years in which the ratio does not become absurdly large or small.

If the ratio does not appear to be constant or changing at a constant rate, a non-linear curve might be used. In this case a graph of historical ratios would be examined to determine the appropriateness of a modified exponential, logistics, or Gompertz curve. The dangers of using non-linear curves without carefully prescribed limits are emphasized.

The data requirements are the same for both the manual and the computer version of the ratio technique. Historical enrollment figures for the school system for which the projections are being made must be available, as must historical enrollment or population figures for the larger area, and enrollment or population projections for the larger area.

Prior to the execution of the ratio technique procedures, a decision must be made regarding the selection of an appropriate larger area, and a suitable measure of trends within this area.

If both historical data and acceptable forecasts are available for the public school enrollment for the larger area, this measure will probably be the most effective variable to use as a measure of trends in the larger area. However, reliable forecasts of population are more likely to be available. This measure may also be used. The principal criterion for the selection of a larger area is the reliability of available independent forecasts. In general, the smallest area containing the local school system for which valid forecasts are available should be used. This generalization is based upon the assumption that conditions in a local school system are likely to be more reflective of conditions in a smaller area, such as the city or county in which the school system is located, than of conditions in a larger area, such as the entire SMSA or the state. If this is the case, then school system enrollments would be more clearly responsive to changed conditions in the smaller area.

Once the data is assembled, the forecast ratios may be applied to an available forecast of the larger area population to derive local estimated enrollments for any year over the chosen planning period.

3.3.4 Dwelling Unit Multiplier Technique

The dwelling unit multiplier technique has been identified in Section 3.2 as a useful alternative to the three forecasting techniques presented earlier. It is particularly applicable to rapidly growing school systems where a relatively large portion of the increase in enrollment has been (and is expected to be) attributable to residential development. This technique requires more extensive data than do the other techniques and thus may not be feasible for some school systems. Historical data is required as to the number of dwelling units (by type of unit if possible) and the yield factor applicable to these dwelling units (i.e., the average number of public school children in each dwelling unit, by dwelling unit type if possible). Where this data is available or obtainable, the dwelling unit multiplier method may represent a valid enrollment forecasting technique.

The School Facility Planning System presents a set of procedures for implementing the dwelling unit multiplier technique. Ideally they should be executed for each type of dwelling unit within the school district's boundaries (e.g., single family residences, apartments, duplexes, etc.). However, data pertaining to the number of each type of unit, and particularly the number of students residing in each dwelling type, may require more collection effort than is feasible. It is, therefore, possible to perform the procedures with all dwelling unit types grouped together. Nevertheless analysis by as fine a breakdown of these dwelling unit types as possible is recommended to enhance the validity of the resulting forecasts.

Three basic procedures are involved in the estimation of future enrollment levels using the dwelling unit multiplier technique. The first is the calculation of historical yields for each type of dwelling unit which is explicitly examined. Where data is already available for these yield factors, this initial procedure may be omitted. However, in instances where the past values of these yields are not known, a random sample of the total enrollment can be selected for each of the years included in the historical observation time span. The type of residence of each of the students in this sample is then determined. On the basis of the results of the sample, an estimate can be made of the number of students who have resided in each type of dwelling unit.

The next step is to forecast the number of dwelling units of each type which is likely to exist in each year over the planning period. A logistics curve may be fitted to historical data regarding the number of dwelling units of a particular type in order to derive estimates of future dwelling units of this type.

The yield factor must then be forecast. If no trend is discernible from the historical values for the yield factor, the average of these past yields may be used as the forecast value. If, however, some trend is exhibited, a method is included to extrapolate this trend into the future. Past yield factors may be regressed against time in order to forecast the yield for each type of dwelling unit.

Once forecasts have been generated for future yields, they may be applied to the forecast dwelling unit levels to derive estimates of future total enrollment levels for each year up to the planning horizon.

3.3.5 Multiple Regression Approaches

After the current procedures survey (Phase 2 of the project), it was believed that a new technique might be designed for long-range projections. The existing techniques were recognized to rely heavily on intra-school district data which often merely reflected various features of the enrollments themselves (such as dropout rates, retention rates, cohort survival measures, etc), thereby limiting the usefulness of such techniques for long-range forecasting purposes. An attempt was made to develop a technique which would incorporate several more fundamental socio-economic factors affecting future enrollment levels.

Three basic effects were identified which were thought to impact overall future enrollment trends. Enrollments were recognized to be a function of the absolute size of the district in terms of the number of households (or dwelling units), the age composition of the population, and the birth rate. A change in any of these factors was identified as having a substantial impact on future enrollment levels; hence these three effects were to form the basis of the model. The immediate question was how these effects could be measured historically and how they could be forecast. The paucity of available data was recognized as a problem which was compounded by the nature of school district boundaries that are infrequently contiguous with the boundaries of other jurisdictions. Therefore an effort was made to develop a model which would require only data that is readily available or which requires a modest collection effort.

The unlikelihood of obtaining even historic data that would directly measure the three factors was recognized. Emphasis was therefore placed on identifying surrogate variables for which historical data was readily available and for which relatively valid independent forecasts might be generated. The model would require that at least one surrogate measure be included to reflect each of the three above identified phenomena. Experimentation was conducted with building permits and electrical hookups as a proxy for the absolute number of households; with student age and mean grade as a proxy for school district age composition; and with national and state birth rates as a proxy for local birth rates.

The multiple regression approach was not successful, primarily because of problems associated with data. Satisfactory surrogate variables were not developed (e.g., attempts to use mean grade as a proxy for mean age were gradually recognized as invalid), and the difficulty of obtaining reliable independent variable projections was not overcome.

The capability of building multiple regression models was developed, however, and is included in both the basic support system and a separate program (Appendix D - Statistical Analysis System). Users are encouraged to experiment with these computer packages in order to develop a multiple regression oriented model that works.

Each package allows consideration of up to six independent variables. The Statistical Analysis System incorporates a distributed lag, artificial orthogonalization and autoregressive least squares routine in order to reduce problems of multicolinearity and serial correlation. It incorporates algorithms developed by B.T. McCallum and Shirley Almon.[35,36]

The logical sequence of this program is outlined as follows:

1. Each variable (dependent and independent) is converted to natural logarithmic form.
2. A set of q points x_j are chosen in the interval $[0, n]$, where q + 1 is the degree of the polynomial to be used for the distributed lag estimation, and n is the number of lagged periods to be considered. In addition to the q points x_j, x_0 is set equal to -1.0 and x_{q+1} is set equal to n. The q points x_j are (in fact) distributed equally along the interval $[-1, n]$.
3. Lagrangian interpolation coefficients ϕ_j (i) are calculated as:

$$\phi_j(i) = \left\{ \frac{(i - x_0)(i - x_1)\ldots\frac{(i - x_j)}{(i - x_j)}\ldots(i - x_{q+1})}{(x_j - x_0)\ (x_j - x_1)\ldots(x_j - x_j + 1)\ldots(x_j - x_{q+1})} \right\}$$

$$\text{for } j = 1,\ldots,q \quad \text{and} \quad i = 0,\ldots,n-1$$

4. A set of q artificial variables A_i are calculated as:

$$A_{tj} = \sum_{i=0}^{n-1} \phi_j(i)\, X_{t-i}$$

where t represents the time period and where x is the distributed lag variable.

5. A composite matrix X^* is constructed as $X \vdots A$ where X is the matrix of regular independent variables and A is the matrix of artificial variables which have been calculated in Steps 2-4. Thus X^* is a $T \times (k+q)$ matrix where T is the number of observations for each variable and k is the number of regular variables.

6. Each variable in X^* is standardized by

$$x_i = \frac{X_i^* - \bar{X}^*_i}{\sigma x_i^*}$$

where X^*_i is the ith variable in the X^* matrix, and where $\bar{X}^*_i$ and σx_i^* are the mean and standard deviation of this variable.

7. The correlation matrix R is computed as

$$R = T^{-1} X^{*\prime} X^*$$

8. The eigenvalues and eigenvectors of this R matrix are computed.

9. A matrix W is formed, where each column of W is an eigenvector. The first column of W contains the eigenvector which corresponds to the largest eigenvalue; the second column of W contains the eigenvector which corresponds to the second largest eigenvalue, and so on.

10. A matrix of principal components Z is computed as

$$Z = WX^*$$

11. Z is regressed on the dependent variable y by

$$\hat{\alpha} = (Z' Z)^{-1} Z' y$$

where $\hat{\alpha}$ is a vector of estimated regression coefficients which are applicable to the principal components.

12. The $\hat{\alpha}_i$ coefficients are transformed into $\hat{B}_i$ coefficients which are applicable to the variables in X^*. This is accomplished by substituting a column of zeros for certain columns in the W matrix. The columns in W for which such substitution is made are done according to the value of $\lambda_j/(k+q)$ where λ_j is the eigenvalue corresponding to the jth column in the W matrix. The number of columns deleted, d, is determined arbitrarily by

$$.95 \leqslant \sum_{j=1}^{(k+q)-n} \lambda_j / (k+q)$$

The $\hat{B}$ vector is thus computed as

$$\hat{B} = W^* \hat{\alpha}$$

where W* is the W matrix after n columns have been changed to contain all zeros.

13. The unstandardized values of B are computed as

$$\hat{B}^*_j = \hat{B}_j / \sigma_{x_j}$$

14. The distributed lag weights are then computed as

$$\hat{W}(i) = \sum_{j=1}^{a} \phi(i) \; B^*_j$$

$$\left\{ (\text{for } j = k+1, k+2, \ldots, k+q \text{ in } \hat{B}^*_j) \right\}$$

15. The estimating equation is thus

$$y_t = \hat{B}^*_0 + \hat{B}^*_1 X_1 + \hat{B}^*_2 X_2 + \ldots + \hat{B}^*_k X_k + \sum_{i=0}^{n-1} \hat{W}(i) \; X(k+1)_{t-i}$$

3.3.6 Enrollment Forecasts by Grade, Area, and Race

Several procedures have been presented which may be used to forecast the total school district enrollment level in each year over the planning period. Total enrollment estimates should provide useful information about the general magnitude of future facility needs. The specific nature of these needs, however, may vary according to the distribution of the total enrollment among the different grades included in the school system. The School Facility Planning System, therefore, provides a methodology whereby enrollments may be forecast for each grade level.

Users who have generated the total enrollment forecast by employing the cohort survival technique will, of course, already have estimates for each grade. If, however, the time trend projection, the ratio, or the dwelling unit multiplier methods were used, or if some alternative method was used which did not encompass specific grade-by-grade estimates, total enrollments must be allocated to the various grade levels.

The method used for deriving enrollment forecasts for each grade is the cohort survival technique.

However, because it is assumed that the estimated total enrollment level for any particular year is more accurate than an estimate for a particular grade in the same year, an adjustment is made. The grade specific estimates are adjusted according to the magnitude of the cohort survival total estimate relative to the total enrollment estimate derived from some alternative procedure. The latter value acts as a control total for each year over the planning period.

The adjustment factor is calculated for each year as follows:

$$a_t = E_t / S_t$$

where a_t is the adjustment factor for year t of the planning period, E_t is the total enrollment forecast serving as the control total, and S_t is the total enrollment forecast derived using the cohort survival technique. The estimates of enrollment in each grade which have been generated using the cohort survival technique are then multiplied by the adjustment factor to derive the estimates by grade.

The same general approach of adjusting to a control total is recommended for making enrollment projections by sub-geographic areas within the district or by race. Projections of student distribution within the district are necessary to conduct the attendance boundary or site selection activity described in Chapter 6. Procedures are recommended for making independent projections for several large regions in the district and then adjusting to the district-wide total. Each regional projection is then allocated to smaller areas or grids on the basis of dwelling unit distribution. Projections by race may be made by any of the previously described techniques, providing, of course, that historical minority enrollment data can be assembled.

3.4 Conclusions

A necessary result of the logic of prediction was articulated by Hajmal over twenty years ago:

> The consumer of forecasts does not realize that, so far as predictive accuracy is concerned, much of the elaborate technique of forecasters is expended in vain; crude methods could have achieved equally good results. However, much as we improve our tools to take care of all that happened in the past, something will sooner or later crop up for which we are unprepared.[37]

Predictions are based either on what happened in the past or on arbitrary assumptions. Since there is no guarantee that what happened in the past will be any guide to the future, and no guarantee that one arbitrary assumption will be better than any other arbitrary assumption, there will always be great uncertainties. As Braden et al. comment: " ...large differences between forecasts and subsequent actual enrollment are more often related to changing local trends and conditions than to specific methods applied, more often a function of the 'clairvoyance' of the planner than his technical prowess."[38]

These problems are inherent in any forecasting method. They call into question the utility of expending substantial money and time on developing ever more sophisticated forecasting models unless there is some indication of payoffs that will make such outputs worthwhile. Such indications, if they are to come, will take one or both of two forms: 1) Comparisons between (or among) methods; further development of abstract models, with no evidence that they work any better than other existing models, hardly seems worth the effort; and 2) case studies of the actual application of such models. Until such models are applied and the users relatively satisfied, it is hard to determine whether a technique has practical application. Only actual experience with a model will determine whether school districts are going to be able—let alone likely—to use it; or whether the time and data demands which the model makes on the school system are too great for the anticipated return.

Further "practical" as well as technical research is in order. It would focus on the development criteria for future models. One obvious question which could be subjected to this kind of research is: "What are the acceptable margins of error to the school administrator?" Obviously, any administrator would rather have better estimates than worse estimates. But at some point, when evaluated in terms of the practical alternatives open to a school administrator, further sophistication in forecasting methods becomes an exercise in technical virtuosity rather than anything related to the quality of educational planning.

Continuing in this line of thinking, one must also remember that in America educational decisions are, at best, political matters rather than technical matters. No increase in the accuracy of a forecasting model is necessarily going to make it any easier to get a bond issue passed. In fact, one might go so far as to argue the opposite: as forecasting models increase in sophistication, it will be harder to convince voters of their usefulness. Especially in periods of declining enrollments it is naive to assume that school closings are going to be based solely on technical considerations.

Whatever method is chosen to make predictions, the forecaster must use a substantial amount of common sense: forecasters must be familiar with the community and determine any demographic or physical changes which would call into question projections derived from historical patterns. The School Facility Planning System has stressed the importance of judgment and flexibility so that school planners will adjust the results of the technical procedures if those results do not seem consonant with what the local planners know about their community.

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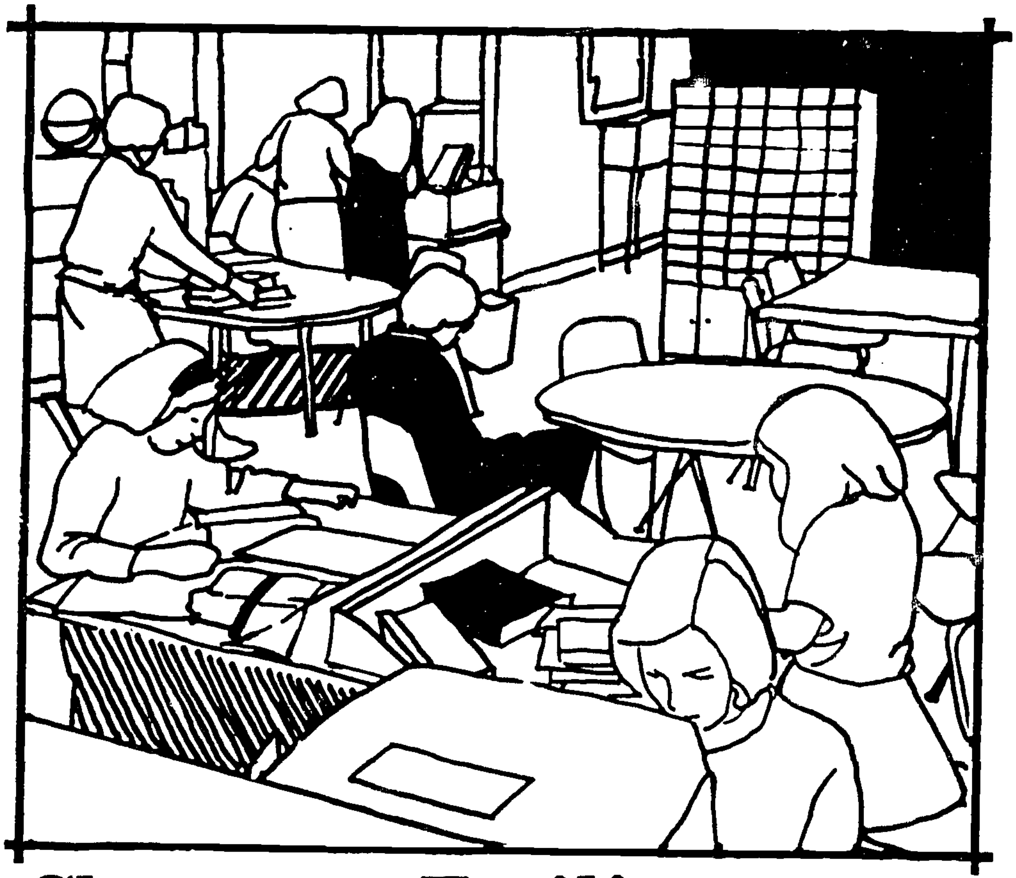

Chapter 4: Facility Analysis

Once public school enrollments have been projected, the task of the school planner is to translate this projection into physical space requirements. The procedures for doing this can be very simple or complex. For example, expected enrollments may simply be divided by the desired class size to determine the number of required teaching stations for an elementary school. Alternatively, the amount of time each student attends school may be divided by the possible attendance time; multiplied by the expected enrollment; divided by a utilization rate, and finally divided by an average class size to determine the number of teaching stations needed for a secondary school.

Either of these approaches involves expressing the school district's educational programs in terms of standards and policies which relate enrollment to physical space. These standards and policies are then applied to the projected enrollment levels to determine the needed space. The district's existing and planned teaching stations are determined by an inventory of availability and adequacy. The number of existing, adequate teaching stations may be compared to the expected number of required teaching stations in order to identify any potential surplus or deficit of space over the planning period.

4.1 The Problem

The process described above is relatively straightforward. The school planner is, however, faced with a number of questions which must be answered before the process can begin. First, is the level of detail at which the study is to be conducted. Is the aim of the study to ascertain a gross measure of space needs on a district-wide basis, to examine facility needs at the elementary or secondary levels independently, or is it to determine the projected surplus or deficit of space for specific kinds of subjects in special schools? The answers to these questions will determine the type, amount, and detail of data to be collected. This will in turn have an influence on the length and complexity of the planning process.

Once the project's focus has been determined, the planner must translate the district's educational program into a specific set of standards. The proposed number of students per teaching station or the number of square feet per student will be a significant determinant of the projected deficit or surplus of educational space. If the standards established at the start of the project are not considered valid for the entire planning period, they must be modified in subsequent years. For example, a shift in the district's educational philosophy could place greater emphasis on vocational rather than academic subjects, thereby changing the needed facility configuration. In establishing standards and policies, the planner must be aware of potential changes and, if possible, incorporate them into the planning process. As the planning horizon is expanded, the difficulty of choosing appropriate standards increases.

To determine the amount of space in existing school buildings, the issue of adequacy must be addressed. Those teaching stations which are included in the available supply must be adequate in terms of size, auxiliary facilities, acoustics, etc. The question of adequacy is even more important when conducting a detailed analysis at the secondary level. As the educational programs change, some teaching stations may no longer be adequate (e.g., academic space may not be readily adaptable for vocational programs). The age of the building must be taken into account to determine whether teaching stations will be of acceptable quality throughout the planning period. A utilization factor may also be employed. Many districts prefer that not all teaching stations be scheduled for every period in the day. The utilization factor can be used to temper the available space with the rate at which they should actually be occupied for teaching purposes in any given day

At this point in the process, the standards are applied to the expected enrollment levels to determine the amount of space needed. Required space is then compared to the available space to determine the expected surplus or deficit of space. The facility planner must make recommendations based on these findings. These recommendations can include "structural" (e.g., building a new school) and "non-structural" (e.g., modifying the educational standards or programs) solutions. The planner must also consider how the recommendations can be implemented. If the conclusion is to expand or contract the physical space, the proposed type, size, and general location must be examined. If the decision is to modify the use of existing space, the courses, schools, and/or standards to be affected should be specified.

The problems of the facility planner center around the selection of standards and policies which accurately express the school district's educational programs. Quantifying the district's philosophy will significantly influence the results of subsequent calculations. In turn, the conclusions reached by the planner will influence future educational programs throughout the district.

4.2 State of the Art

School administrators have been addressing the problem of determining facility demand since the one-room school could no longer house increasing enrollments. As the number of students in an area grew, determining the size and arrangement of school buildings became a problem. The first answers to this problem focused on one room per grade in the elementary school and one room per subject area in the secondary schools. Solutions then, as now, were tempered by initial construction costs and subsequent operating costs. Techniques for analyzing school facility needs have slowly evolved from these very subjective approaches to more rigorous calculations. The following section summarizes this development.

Among the first tools used by school administrators to determine facility need was the school survey. Surveys have taken many forms. Depending on the specific needs of the school district, the survey has been used to 1) determine community desires regarding future educational program changes, 2) categorize existing facilities in terms of adequacy and need, and 3) enumerate various population characteristics. The data collected in these surveys is typically aggregated, analyzed, and used to modify existing educational policies or as the basis for a proposed building program. Advances subsequent to the initial school surveys can be examined in terms of two broad categories: techniques for calculating the demand for space and techniques for evaluating the supply of space.

4.2.1 Calculating the Demand for Space

Early attempts to quantify the demand for school space tended to be subjective, and in some cases used only when they could be reconciled with certain preconceived ideas. More recently, efforts have been made to redefine the procedures for determining facility needs into more precise mathematical formulae. These formulae have been devised to minimize the role of subjective opinions. Several of the more commonly accepted formulations include work done by Marion Conrad, Basil Castaldi, and the Dallas, Texas Independent School District. The first methodology was developed in 1952 by Professor Marion J. Conrad of Ohio State University.[1] His approach determines the capacities of existing schools through the use of the following expression:

$$BC = \frac{TS \times DS \times T \times E}{PP}$$

where

BC = the building capacity which is the number of students that can be accommodated by existing facilities in a given subject area,
TS = the total number of teaching stations in a given subject area,
DS = the desirable average class size for the particular subject area,
T = the total number of effective periods of instruction per week in the schedule of classes,
E = the average total school enrollment for a given period of time,
PP = the average total number of pupil periods of instruction per week in the schedule of classes.

Conrad's approach is based on the assumption that "capacity is integrally related to the educational program and policies of each school system."[2] This premise would certainly seem to be sound.

A potential difficulty with this approach is that the units derived in the intermediate steps of the procedure are quite complex and thus may have little intuitive appeal. Values which are very large relative to the basic input values are likely to result. The appropriate definition of these large values may confuse the rationale upon which the procedure is based. A more detailed break-out of certain variables in the equation might facilitate more complete understanding of this rationale on the part of the user.

Conrad dismisses the need for explicit consideration of the desired utilization rate and assumes that this factor is implicitly incorporated into the formula. He assumes, in effect, that all teaching stations may be used for instruction during every period of the school week. Because this is obviously not always the case, an adjustment process is necessary. While such a process is described by Conrad, it would appear that the adjustments implied may be somewhat arbitrary in nature. The inclusion of a user specified adjustment capability in the form of a desired utilization rate would seem more useful. It would allow for a more accurate reflection of potential discrepancies between various school systems.

An alternative approach for calculating space demands was developed by Professor Basil Castaldi during the 1960's.[3] This approach is based upon the following relationship:

$$TS = 1.25 \left(\frac{E}{C} \cdot \frac{n}{N} \right)$$

where

TS = required number of teaching stations,
E = number of students enrolled in a given class,
C = desired class size,
n = number of periods per week pupil attends a given class,
N = number of periods in the school week.

The Castaldi formula again is based on the translation of the educational program into a set of standards to be used in the formula. An advantage of this formulation is that each element may be readily interpreted. The number of classes needed for a given subject is $\frac{E}{C}$. The ratio of total periods which must be devoted to this class is $\frac{n}{N}$. The multiplication of these two numbers yields the number of teaching stations needed. Since all classrooms are rarely available for teaching purposes during all periods of the day, the number of teaching stations is multiplied by a utilization factor (1.25) to determine the actual number of teaching stations needed. The standardization of the utilization factor in the Castaldi model may present a problem in that this factor varies from one local educational authority to another, depending on the educational program and the physical juxtaposition of the teaching stations. A more appropriate approach might be to allow this value to vary, and to be specified by the user to reflect the desired level of flexibility. The Castaldi approach also fails to explicitly consider procedures for determining the future enrollment per subject area. It can obviously vary as a function of total school enrollment and/or preferences and requirements to participate in a given subject area.

A third formulation of the facility need problem is presented in the Enrollment and Facilities Projection Program developed by the Dallas Independent School District in 1975.[4] The approach used here may be summarized as follows:

$$R = T \times U$$

where

R = rooms needed for a given subject,
T = teachers required for a given subject.
U = utilization factor

and

$$T = E \times \frac{F}{C}$$

where

T = teachers required for a given subject,
E = total enrollment for the school,
F = fraction of students taking a given subject,
C = average number of pupils in a given subject that a teacher meets on an average day.

The Dallas model is a computerized technique for generating estimates of future facility needs in terms of both the required number of teaching stations and the required number of teachers. The actual inputs to the technique are more detailed than those indicated by the above equation. In some respects the mechanics of the procedures are similar to those outlined by Conrad. The difficulty encountered in the interpretation of the intermediate variable calculations may, therefore, still be present, but it is less constraining when these intermediate calculations are done internally by the computer.

The Dallas Simu-School model is a highly structured approach. The extent to which this rigid structure can be easily transferred to other school districts with their own unique features and computer system is as yet unclear.

4.2.2 Evaluating the Supply of Space

Discussion thus far has concentrated on techniques for calculating future facility demand. The supply of facilities must also be addressed in the formulation of a valid facility plan. A critical aspect of this analysis is the adequacy of the facilities. Adequacy can be measured with respect to state requirements, the requirements of the overall educational program, and the needs of an individual subject area.

Many systems have been devised for rating the educational adequacy of existing school facilities. A typical system was developed by McLeary in his Guide for Evaluating School Buildings.[5] Like many it used the concept of a penalty system. A perfect score is assumed initially. When a particular item does not meet accepted standards, a penalty is assigned and deducted from the initial score. The evaluation is divided into the following general areas: site, buildings, service systems, classrooms, and special rooms. Each category is assigned a maximum possible score which, when combined, equals 1,000. The completion of the entire survey is not necessary to determine the adequacy of existing teaching stations. In keeping with most school survey procedures, McLeary's guide increases the probability of a comprehensive valuation but does not eliminate the opportunity for subjective judgements.

A more recent attempt at constructing a methodology to determine school building adequacy was developed by Carroll W. McGuffey as part of the Chicago component of project Simu School.[6] The areas of evaluation used in this approach are: plant performance, utilization efficiency, school plant effectiveness, user perceptions, and economic feasibility. The plant performance component is of most direct use in determining the adequacy of classrooms for instructional purposes. The evaluation method consists of a set of performance standards. The ratings for these standards are superior, adequate, marginal, inadequate, and missing. The overall rating level of each room determines its relative adequacy for instructional use.

The procedures described above, as well as several others which are currently available, are satisfactory tools for evaluating the adequacy of existing educational space. The ultimate judgement as to the educational adequacy of any particular space is, of course, in the hands of the user. None of these 'score sheets' should therefore be accepted as complete, but should be viewed as representing an initial evaluation procedure. The findings of such an evaluation must be modified according to the unique characteristics of each school district.

4.3 School Facility Planning System Approach

The approach used in the Facility Component of the School Facility Planning System is not dissimilar to those models which have been discussed earlier. It represents an attempt to synthesize certain of the desirable features of each. The manual and computer versions of the systems have slightly different formulations, but no substantive difference.

The approach converts the expected student enrollment into a measure of the effective impact of this enrollment. Effective enrollment is expressed in terms of the average number of students which must be accommodated at any given point in time during a typical school week. The concept becomes especially important when the analysis is to be conducted at a subject area level of detail. Once calculated, the effective enrollment level is then translated into a measure of facility needs. This translation may be done in terms of the number of teaching stations which will be needed, or the amount of square footage which will be required, or both. Finally, the chosen measure(s) of facility need is compared to the corresponding measure(s) of existing facilities in order to identify the nature and magnitude of any potential shortage or surplus of educational space.

The technique used to translate the projected absolute number of students expected to be enrolled into the number which must be accommodated at any point in time is summarized by the following mathematical expression:

$$E_{ij} = \left\{ N_i \left(\frac{A_{ij}\ W_{ij}}{P_{ij}\ D_{ij}} \right) \right\} \div U_{ij}$$

where

E_{ij} = the effective enrollment level (i.e., the number of students expected to be physically in attendance at any given point in time during a typical school week),
N_i = the total number of students enrolled,
A_{ij} = the average number of courses taken by each of the students,
W_{ij} = the average number of periods per course each student attends in a typical school week,
P_{ij} = the number of periods per day in which classes are held,
D_{ij} = the number of days per week on which classes are held,
U_{ij} = the desired maximum utilization rate (i.e., the average percent of educational space which is to be occupied at any given point in time during a typical school day).

The subscripts i and j associated with the variables refer to the school and subject area (or educational space type) being examined, respectively. For example, E_{ij} is read as the effective enrollment in school i for subject area j.

The level of analysis can be varied depending upon the needs of each school district. The user who wishes to examine each school individually would simply interpret each of the variables in the above equation as applying to a particular school. Those who wish to conduct the analysis for the district as a whole would ignore the subscript i and treat each variable as being applicable to the entire school system. Similarly, the option of computing the expected effective enrollments for individual subject areas (or educational space types) is available. Some districts may want to consider all academic courses individually, others will want to separate those requiring "regular" versus "large" classrooms, and still others will be content to lump them all together.

The next step in this process is to translate the effective enrollment level into some physical measure(s) of the required educational space. Each district has the option to measure the space in terms of the required number of teaching stations (as defined by the user) or the number of square feet (also user defined), or both. In the case of teaching stations, the effective enrollment is divided by the desired maximum number of students per teaching station as in the following equation:

$$RTS_{ij} = E_{ij} \div T_{ij}$$

where

RTS_{ij} = the required number of teaching stations,
E_{ij} = the effective enrollment level,
T_{ij} = the desired maximum number of students per teaching station.

This result may be translated into square feet by simply multiplying the number of teaching stations in each space category times the average square feet per category. For those districts that wish to directly compare a square footage measure of future facility needs (i.e., without first considering teaching stations) the effective enrollment would be multiplied by the desired minimum number of square feet per student as in the following equation:

$$RSF_{ij} = E_{ij} \times F_{ij}$$

where

RSF_{ij} = the required amount of square footage,
E_{ij} = the effective enrollment level,
F_{ij} = the desired minimum number of square feet per student.

The final step in the Facility Component involves a comparison of the required facilities to the existing school space. This comparison identifies any gap between estimated future facility needs and the existing facilities. Calculation of the space surplus or deficit will necessitate that the required and existing facilities be measured in the same units. Either of the following equations may be used:

$$CD_{ij} = RTS_{ij} - ETS_{ij}$$

where

CD_{ij} = the capacity differential (surplus or deficit),
RTS_{ij} = the required teaching stations,
ETS_{ij} = the existing teaching stations

or

$$CD_{ij} = RSF_{ij} - ESF_{ij}$$

where

CD_{ij} = the capacity differential (surplus or deficit),
RSF_{ij} = the required amount of square footage,
ESF_{ij} = the existing amount of square foctage.

A number of user decisions must be made to carry out the facility analysis described above. The first decision is the appropriate time horizon The component is not dependent on any specified time interval. It can be used equally as well for a five-year or twenty-year planning period, depending upon available data and the district's situation. The level of analysis is also a user option. The longer the planning period the more difficult and uncertain detailed analysis becomes. The district is best able to know if it is subject to rapid changes in the educational program and if standards which are effective today will be appropriate in the future. Definitions of teaching station and square footage for the school district must be supplied by the user. The definitions established at the beginning of the study should be used consistently throughout the process.

As explained in the handbooks the data requirements associated with the Facility Component include the following:

1. course enrollments for the previous five years
2. average number of class periods per course
3. total student enrollment for the previous five years
4. enrollment forecasts for the planning period
5. number of current and expected class periods per day
6. number of current and expected days per week on which classes are held
7. desired utilization rate
8. desired number of students per teaching station
9. number of existing teaching stations
10. desired number of square feet per student
11. number of existing square feet

The major benefit of the Facility Component is the ability to quickly examine the impact of potential shifts in school policy and/or community conditions. With relatively little effort the school planner can examine the probable effect of alternative enrollment projections. The contribution of alternative physical plans, such as a school closing or a new school, can be analyzed. Similarly the effect of numerous "non-structural" solutions such as more children per space, staggered sessions or even a twelve-month school year, may be reviewed.

Notes:

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3. Basil Castaldi, Creative Planning of Educational Facilities. Chicago: Rand McNally and Company, 1969.

4. William D. Gattis and M. William Dunklau, Enrollment and Facilities Projection Program: General Description and User's Guide. Dallas, Texas: Dallas Independent School District, February, 1975.

5. Ralph D. McLeary, Guide for Evaluating School Buildings, Cambridge, Massachusetts: New England School Development Council, 1956. Other useful systems can be found in Harold L. Hawkins, Appraisal Guide for School Facilities, Midland, Michigan: Pendell Publishing Company, 1973; and Bureau of School Facilities Planning, Profile Rating Wheel: An Instrument to Evaluate School Facilities, Sacramento, California: California State Department of Education, 1973.

6. Carroll W. McGuffey, MEEB: Model for the Evaluation of Educational Buildings. Chicago: Chicago Public Schools, 1974.

Chapter 5: Fiscal Analysis

The fiscal analysis associated with school facility planning can not easily be separated from the fiscal analysis required of all educational planning. Expenditures for capital planning constitute a relatively small fraction of the substantial amount that is spent each year for public education. For example, only about ten percent of the estimated fifty-two billion dollars spent on public elementary and secondary education was for school construction in 1973.[1] This amount has declined from almost thirty percent of total educational expenditures in 1954, and with continuing enrollment decreases, can be expected to decline further.[2] However, the analysis necessary to examine the financial implications of building or closing a school cannot be successfully divorced from the analysis of total school revenue and operating expense forecasts.

5.1 The Problem

Unlike in many countries, United States primary and secondary school education is financed largely at the state and local level. In the 1972-73 school year, less than eight percent of public school revenue derived from the federal government; forty-one percent came from state sources, and fifty-one percent came from local sources.[3] In this latter category, the vast proportion was generated by local property taxes. Within individual states the allocation between sources varied substantially. Therefore, the successful school planner must understand and be able to predict activity at the local and state level.

The fiscal analysis problem has two parts which must be solved simultaneously. First is that of predicting a community's ability and inclination to provide the financial support necessary for a given educational program and the facilities which it demands. The second part is that of selecting the best strategy for carrying out the educational program within defined guidelines regarding standards, policies, and costs. The first aspect involves revenue analysis, the second involves expenditure analysis.

Revenue analysis requires an estimation of a given district's capacity to raise funds, and the inclination of its citizens to tax themselves. Capacity is dependent upon the community's general prosperity, and particularly the valuation of its property which provides the local tax base. Assessed valuation also enters into the equalization factor that most states include in their calculation of unrestricted grants-in-aid to be apportioned to each school district. In those school districts that are legally limited in the amount of bonded indebtedness they can incur, assessed valuation is usually the base by which the limits are established. Thus, assessed valuation is the single most important factor in determining the capacity to provide revenueand incur debt.

The willingness of citizens to pay for education is affected by the moods of Congress, the state legislature, and the local electorate. It is influenced by a community's perception of the need and definition of quality education, and is very much related to the demographic characteristics of that community. The revenue segment of the fiscal analysis problem requires that a planner be able to forecast fundamental growth in assessed valuation, retail sales, and other ingredients of revenue capacity. The planner must also be able to forecast the composition and mood of the local community, state legislature, and, in some instances, courts.

The problem of determining an expenditure strategy for a school system is more complex. Here the challenge is to expend monies in a prudent manner so that the educational goals are achieved, but within carefully prescribed cost limits. In terms of facility planning the goal is to obtain the best mix of space that will house the projected enrollment without squandering funds. The plan necessary to carry out this strategy must contain well defined decision points, the quantities associated with each decision, and some measure of the risk and future consequences of the decision.

Many of the elements that enter into the expenditure strategy will, of course, be beyond the control of the school administrator or planner. Between two-thirds and three-fourths of most local educational authority budgets are devoted to personnel costs, primarily teachers' salaries. A major expenditure item is thus extremely sensitive to inflation and employees' demands. Only limited control over this category can be exerted by varying the teacher-pupil ratio.

Construction, demolition, land, transportation, and debt costs are also sensitive to economic factors largely beyond the school district's control. The facility planner must base the expenditure strategy on answers to many questions:

> What potential savings are associated with alternative sites, designs, materials, etc.?
> What economies of scale might be realized with each alternative?
> When would be the most auspicious time to achieve the lowest costs and interest rates?
> What is the best financial mechanism for supporting the construction, refurbishment, or closing of selected schools?

All of these must be answered within the context of the communities' attitudes and laws regarding public education.

Both parts of the fiscal analysis problem contain a mixture of subjective and quantitative considerations. Any contribution that assists in the solution of this problem must present a structure within which the subjective parts and the analytical tools for handling the quantitative parts can be communicated.

5.2 State of the Art

Fiscal research in the field of education has branched in a number of directions in recent years. These trends are summarized below in terms of three overall categories: General Economic Analysis, Budgeting Systems, and Specific Forecasting Models. No attempt at comprehensiveness has been made; rather a variety of typical research activity is identified.

5.2.1 General Economic Research

The most intensive general research activity has centered around the three-year National Educational Finance Project (NEFP) initiated in 1968.[4] In a series of volumes, this analysis documented the positive and negative features associated with the decentralized system of financial support for American education. Several themes within this general category have received particular attention in recent years. First, the issue of equalizing educational expenditures has received emphasis, partially because of the numerous court challenges to current systems which, in most states, preclude equal expenditures per child. Variations in current expenditure patterns have been carefully documented, and many corrective measures proposed and, in some cases, adopted.[5] A second related focus has concentrated on alternative mechanisms for increasing financial support. In terms of school facilities, many alternatives to the traditional bond issue have been proposed.[6] Associated with this concern has been a series of basic studies into the factors behind educational demand. One after another "ex post facto" correlational study has indicated that measures of community wealth and wealth-related variables are the best predictors of educational demand.[7] Conversely, factors which are more directly subject to school administrator control have been shown to have far less predictive power.

A final theme within the general category of education-related fiscal research has developed recently with the increase in school consolidations and closings. Usually on a case-by-case basis, the fiscal impact of shrinking enrollment and school closings has been analyzed.[8]

5.2.2 Planning, Programming, Budgeting Systems

If the volume of literature is any guide to the importance of an idea, the concept of planning, programming, budgeting, systems (PPBS) represents one of the most important fiscal innovations in education. Since its promulgation by the federal government in the mid 1960's an extensive amount has been written about the merits and techniques of the approach.[9] Knezevich has identified about twenty states that have recommended or mandated the establishment of program budgeting in education.[10] He describes the system as placing a "disciplined emphasis on missions to be accomplished" and consisting of the following cycle of activities:

1. Planning
   - Formulating a future course of action
   - Specifying long- and short-range goals
   - Clarifying goals
2. Programming
   - Generating alternative approaches to goals
   - Clustering activities related to objectives
   - Developing operational plans
3. Budgeting
   - Translating programs into fiscal and non-fiscal requirements
   - Pragmatic classification of planned expenditures
4. Analyzing
   - Specifying major assumptions, constraints and uncertainties for each alternative
   - Determining cost-effectiveness of each alternative
   - Rank ordering of cost-effectiveness index for an alternative
5. Deciding
   - Determining the optimal course of action or alternative for each goal
6. Evaluating
   - Reviewing outcomes and relating each to prior expectations
7. Recycling
   - Feeding evaluative judgements into the system to begin a modified PPBS cycle.

PPBS has been considered most useful in situations where the objectives are difficult to clarify and the relationships between activities and objectives are vague. It is not a particularly dynamic system, and, as such, not directly concerned with the long-term problems of risks or strategies. In this respect its applicability to facility planning situations would appear limited, especially where the relationships between specific activities and objectives are explicit. In these situations the evaluation of risks, the timing of decisions, and the formulation of strategies are more predominant needs.

5.2.3 Analytical Techniques, Models, and Computers

As noted throughout this report, analytical techniques are beginning to be used with growing regularity in many phases of education. Probability techniques, such as decision trees, sensitivity analysis, and expected value calculations; simulation methods, such as cash flow projections, risk-analysis, and Monte Carlo applications; linear programs involving problems of optimal assignment and allocation; and PERT/CPM involving scheduling so that work costs and slippage are reduced; all are being experimented with in many educational settings.[11]

The difficulties of using analytical techniques have been widely documented. First there is the difficulty of formulation. The problem to be analyzed must be organized and quantified in a way that will fit the technique. This can be a complicated task, with the constant danger that the actual problem is misrepresented in the effort to apply a given technique. Obtaining relevant data is typically a large part of the formulation challenge. A second major difficulty is that of performing and interpreting the calculations, once the formulation has been completed. This process can vary in complexity from trivial hand calculations to the employment of hours of computer time.

A mathematical model generally refers to a consistent, coherent, and tractable collection of variables that are related, using one or more analytical techniques. Its construction is largely an intuitive process. The most useful models for fiscal analysis have been simulation models consisting of elementary linear and exponential relationships structured in a modular or "building block" framework.

Scott developed an expenditure forecasting model for a municipal government.[12] Expenditures for education are projected as a function of projected students, teachers, salary structure, and non-personnel items. Debt service is calculated in terms of principal and interest payments using an accounting model. The ability to vary exogenous variables, such as interest rates, and policy variables, such as the level of service to be provided, are built into the model. While designed for the city of New Haven, Connecticut, the methodology and formulas are applicable to many other jurisdictional settings.

A financial projection program has been constructed for the Dallas Independent School District as part of the Project SIMU School Program.[13] Its purpose is to project a budget and overall financial analysis for a medium or large school district. Input data requirements include operational parameters (district identification, minimum foundation program algorithm, years to be simulated, years of historical data, and budget forecasting methods per category); demographic information (enrollment projections and grade level structure); personnel history (number, salary, experience, level of highest degree); state salary schedule (pay grades and steps that make up the minimum foundation salary schedule established by the state); and a variety of miscellaneous finance items (transportation costs, state and local receipts, tax rates, etc.).

The financial projection program is impressive in its detail, but is very much geared to educational programs in the state of Texas. Its potential for transfer and, in fact, its forecasting accuracy must be further evaluated.

Several more generalized models have been developed by private firms for use in multiple school districts. Plantran II is a software package developed originally for financial analysis in higher education.[14] It is more free form than the Dallas system. The user may make independent projections (increasing a data item by a percentage, by an increment, or by the value necessary to achieve a goal), may perform arithmetic operations, and may input independent data. Projections are printed in graphic as well as standard report formats.

The Municipal Impact Evaluation System (MUNIES) is a similar package.[15] Advertised as a tool for evaluating the costs, revenues, and other financial effects of development on government, it has been used in examining school settings. MUNIES has computer-based capabilities that allow a user to enter data and assumptions, conduct basic mathematical operations, and print the answers. Space requirement calculations, salary projections, and the amortization of debt have been produced using the package.

PLANTRAN II and MUNIES are not so much models as support systems for building models which have been used to analyze fiscal problems. In this respect they are like the basic support system used to conduct the computer-based analysis in the School Facility Planning System. The basic support system is a version of the Intech Incorporated FORECASTER. It appears somewhat more versatile than early versions of the above packages because it incorporates regression analysis and time series forecasting capability.

These and many other support packages have been used for fiscal analysis purposes in private industry.[16] Computer languages and packages to support fiscal analysis, particularly simulation models, are readily available from public and commercial sources. The problem is not one of the availability of computer support. Rather the challenge of fiscal analysis is the formulation of any basic model into a structure that makes theoretical and practical sense. Most successful fiscal models have been constructed in an exclusionary manner, starting with a few simple relationships, and then, over time, adding more complex aspects.

5.3 School Facility Planning System Approach

The Fiscal Component of the School Facility Planning System has as its purpose the calculation of debt and cash flow associated with a given plan for providing necessary facilities. This, together with the required space calculations described in the preceding chapter, is the main variable needed for evaluating the efficiency of a proposed school plan.

To calculate the debt and cash flow, it is necessary to project in time all revenues, expenses, and debt commitments. This is accomplished in several parts, each of which is discussed in the following sections.

The approach adopted in the design of the Fiscal Component is similar to that adopted elsewhere in the System. Variables are to be projected in the simplest manner possible by either time series methods, by arithmetic relationships between previously determined variables, or by regression techniques. Sufficient flexibility is allowed so that whatever technique seems to be most applicable in a given situation may be used.

The models which have been assembled for this project are both elementary and flexible. It was recognized as fruitless to attempt sophisticated mathematical applications in the generation of long-range projections involving such a large number of economic and social variables. Each variable which could be predicted with some accuracy would need to be combined with others which could change drastically in response to economic pressures beyond the immediate community.

The main purpose of a system of this type is to give planners a way to view the consequences of their assumptions and observations in a quantitative fashion. Human beings have great intuitive talents, but their ability to integrate a large number of sound intuitive notions into sound decisions is often poor. The hope is that the System will inject more integrity into the intuitive statements.

The organization of the Manual Version of the User's Handbook is somewhat different from that of the Computer Version. However, the basic elements of fiscal capital planning and budgeting are incorporated in each. These include projecting capital costs, determining assessed valuation and debt capacity, and calculating total revenues and expenditures.

5.3.1 Projecting Capital Costs

The major variables which must be examined are the number of square feet of space which will be built for each year that construction is planned; the number of square feet of space which is planned to be rented; a renting cost figure; a building cost index and land costs.

The amount and dates for obtaining additional space are part of the strategic plan to be tested and as such should be based on the judgement of the planner. The building cost index is an estimate of the relative cost of construction from year to year. Since general inflation and labor and material costs enter into this index, it is not an easy number to estimate. One commercially available source is the Dodge Manual for Building Construction Pricing and Scheduling. Projecting the values of the index into the future is a precarious endeavor.

Recommended possibilities are by least squares exponential curve fit, by calculating the historical percentage increases and projecting these increases linearly, by using an average percent annual change, or, finally, by assuming one or more rates of inflation. None of these techniques can be proven better than the others. Whichever one is chosen, the choice should be noted, and the sensitivity of the final plan to this variable should be estimated.

Presumably, renting costs will increase at approximately the same rate as building costs, so a building cost index could be used to estimate these also. Translating the projected amounts of building space to be leased or constructed into costs is accomplished by multiplying by the present-day cost per square foot weighted by the building cost index.

The cost of land acquisition is entirely dominated by local supply and demand characteristics. No general methods for obtaining estimates of land costs are given. Local realtors and planning agencies will probably represent the best sources of cost estimates.

5.3.2 Assessed Valuation and Debt

The projection of assessed valuation has two purposes for this project. The first is that of determining the school district's capacity to borrow money. The second is to determine the base for levying local property taxes.

In projecting assessed valuation, the economic growth of the community must be considered. Both the residential growth and commercial growth will need to be estimated. The value of property in a community is largely a matter of supply and demand. For various reasons, communities often will suddenly switch from a stable economic state to a surge of growth or decline. After some time elapses, supply and demand will again tend to bring the community to a state nearer equilibrium, where more gradual trends will be resumed. Each of these situations, either the stable or the rapidly changing, results in one of several characteristic curves. These curves are the modified exponential curve, logistic, and/or Gompertz curves. The projection presented in the School Facility Planning Project is one of determining which growth situation applies to the community and then fitting the appropriate curve to the data.

Since a school district will usually include a variety of residential and commercial activity, it is recommended that disaggregated analysis be conducted, where possible, in terms of both land use types and geographic areas. Data and time will, of course, be constraints. The results would be aggregated to obtain a district-wide forecast.

Two additional factors in forecasting assessed valuation should be accounted for. First is the general inflation factor, growth over and above that due to supply and demand pressures. Second is the fact that a property's assessed value in some communities may not be adjusted for many years to reflect changes in the true market value. To address these considerations, the serious analyst may use more detailed forecasting procedures. Both versions of the System allow the user to analyze the assessed valuation left unchanged from the previous year, the net adjustments on the assessment of old properties, and the assessments due to new construction. Information from the local tax office and building department may provide sufficient information to allow valid projections in this manner.

The other variables associated with assessment debt are the district's bonding capacity as set by state regulations, payments on principal and interest, and total debt. A district's net bonding capacity is calculated as the difference between indebtedness and gross bonding capacity. It is affected by debt commitments already made and by future indebtedness proposed to support the facility plan.

5.3.3 Revenues

Revenues derive largely from local, state, and federal tax sources. Other sources may be tuition, transportation charges, fees, and earnings on investments. The School Facility Planning System provides the ability to project revenue on a gross level (e.g., local property tax, state grants-in-aid, and others) or a detailed source by source level. The decision is up to the user.

Local revenue is calculated by applying an actual or proposed rate against the projected tax base. Specific state foundation formulas have not been presented, but can be built into the

System with relative ease. Accurate revenue projections require insight into the mood of the electorate and their representatives. Since this is not entirely possible, the planner must take into account the consequences of having actual conditions deviate from the course on which plans were based. Projections must be made, but their base will be largely intuitive. Determining just how critical an action at some decision point really is, is largely the purpose of a planning system.

5.3.4 Expenditures

To project total district expenditures, one must combine all operating expenses with the anticipated debt service expenses. Operating expenses can be divided into those costs which are related to numbers of teachers, enrollments, and/or the number and size of school buildings. A major variable is teachers' salaries. Recently teachers' salaries have risen more rapidly than the per capita income of the United States as a whole. In projecting salaries it will be necessary to make some basic assumptions regarding inflation rates and per capita income and their relationship to teachers' salaries. The Office of Business and Economic Research in the United States Department of Commerce provides long-range projecting of per capita income. It is suggested that one method of projecting teachers' salaries is that of forming a simple linear relationship between teachers' salaries and per capita income either by regression or by using some recent ratios.

The projected per capita income should bear some relationship to the projected building cost index. Both will be influenced by inflation. If building costs rise appreciably faster than per capita income, it will be accounted for by the fact that either the wages of construction workers or the cost of materials is rising faster than average income. The reality of inflation may also cause revenue and expenditure forecasts to follow similar patterns. This is not certain, however, because slow reassessment policies and tax payers' revolts in many communities insure that school district revenues will not always be sensitive to inflation.

The other operating expenses belong to categories such as school materials and supplies, teachers' benefits, and building operating costs. These should be disaggregated to whatever level is necessary to give a good picture relative to facility planning. Simple linear expressions relating these variables to the projected enrollment, facility needs, or teachers' salaries should be adequate to make the projections.

5.4 Conclusion

The preceding sections describe a planning environment in which a great amount of uncertainty will exist. Nearly all the variables which are significant will depend upon certain assumptions which may or may not be valid. Generally no scientific analysis or projection techniques can predict the validity of these assumptions throughout the time period for which decisions will be consequential.

The System recommends that the question of risk be related to a given plan. If the plan is implemented, what might be the consequences if the assumptions do not hold? Thus for a given facility plan, analysis requires that the assumptions involving enrollment levels, building costs, operating costs, teachers' salaries, and the community's willingness to levy taxes should be altered and new calculations made based upon new assumptions. For the new calculations, the cash flow and space differentials should be examined. The assumptions which should be tried are largely an intuitive matter. All tentative assumptions should be plausible. Enough calculations should be made to provide an idea as to the range of assumptions for which a given plan will remain adequate.

The question of sensitivity refers to the decision points for a given strategic plan. Each plan for providing facilities has points in time at which a major commitment is being made. These points have both quantities and a date associated with them. Tax rate increases, building construction, building closings are examples. Each of these decision points should be tested for its sensitivity to both time and quantity. To do this all assumptions regarding future levels of enrollments and salaries should be held constant while the amounts and dates on the decision points are allowed to vary. The resulting effects on the two bottom line variables, the cash flow and the space requirements, can then be noted. The relative importance of a decision point will become evident by this procedure.

Notes:

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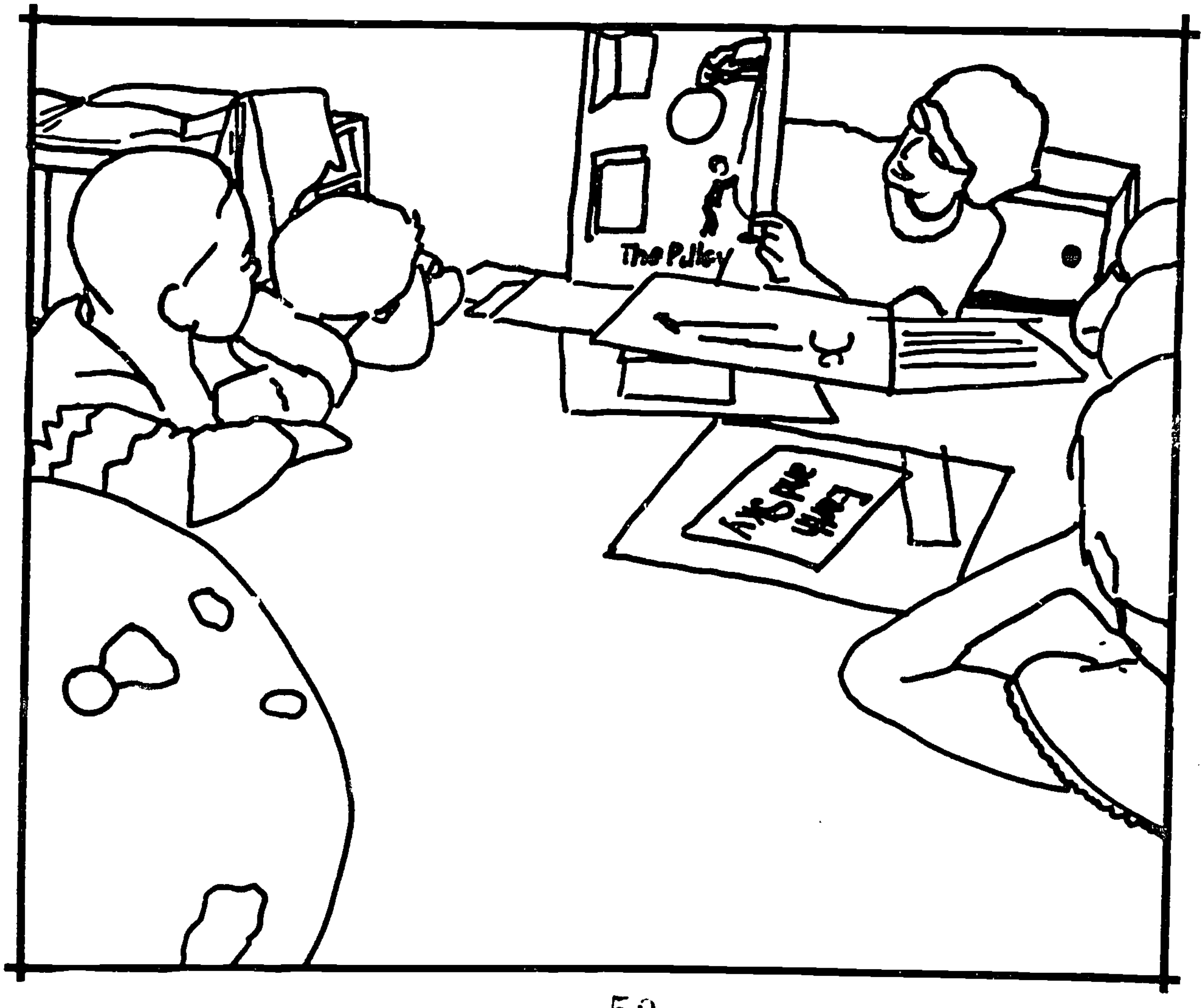
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Chapter 6: Geographic Analysis

The geographic distribution of future enrollments within a school district will have a significant impact on the selection of attendance area boundaries and on the selection of sites for new schools or school closings. Geography is, therefore, a major determinant of costs in many school systems. A number of mathematical models related to geography may be applicable to the locational problems faced by school district administrators.

6.1 The Problem

The locational aspect of school facility planning includes selecting policies that will minimize transportation, operation and capital "costs." These policies must recognize legal and political constraints within the community. Some of the difficulties associated with locational planning include identifying the constraints; measuring costs, both for the immediate and long-range future; and developing a practical set of guidelines, unencumbered by massive data collection and calculation requirements.

A given school district will have a limited number of options that are considered feasible. It may have only the option of reassigning students to existing schools in the district; or it may have a wider range of possible solutions, including the opening of new schools or the closing of surplus schools. Thus many variations on the basic problem exist according to which category of action is possible.

In addition, most school districts will be subject to certain extraneous requirements that dictate certain modes of operation. Some restrictions may be generated locally. For instance, a strong neighborhood organization may insist that all the children of that neighborhood be assigned to the same school. Traffic hazards may require that children from a certain area not attend the school nearest their home.

The extraneous requirements may also be more widely applicable. A great many school districts are working to resolve problems of racial imbalance among their schools -- some by court order and others on their own volition. Though many criteria have been suggested to measure the extent of racial balance, the one most frequently imposed by the courts is that each school in the district reflect, within a specified tolerance, the racial composition of the district as a whole. Thus, if the symbol B denotes the percent of minority students in the district as a whole, and the symbol V represents the maximum allowable deviation from that percentage, then the percent minority students in any school in the district must lie between the limits B-V and B+V.

The many possible interpretations placed on the word "cost" complicate the geographic analysis problem. The most direct interpretation is the true cost to the district of its students travelling to their assigned schools by whatever conveyance, whether it be district supported school buses or by foot. Rarely can these costs be determined with any degree of precision.

It is necessary, therefore, to develop substitute measures for true transportation cost which, though not precisely reflecting the true cost, vary in rough proportion to it, and can be measured. These substitutions are called "interpreted costs." For example, one could express the cost in terms of the total distance of students in the district from their assigned schools. As long as all students provide their own transportation, or as long as the school district provides transportation to all its students, it is a reasonable assumption that the true cost to the district will be directly proportional to this total distance. Thus, a scheme which minimizes distance will also, in effect, minimize cost.

This attempt to develop a working concept of cost is challenged when a district implements a mixed bussing policy -- one in which some students are bussed and others are left to provide their own transportation. Suppose that a district adopts the policy of bussing all students living over one mile from their assigned school. The true total cost to the district is then the sum of two different types of cost. The first is the actual cost to the district of providing the bussing program. The second cost is the interpreted cost, perhaps in terms of good will, of the students who must provide their own transportation.

The question of designating attendance area boundaries is comparatively simple relative to the location decisions involved in selecting sites for new schools or for school closings. The prime factor which is of interest in the Geographic Component of the User's Handbook is again the costs associated with various locational alternatives. School operating and capital costs, as well as transportation costs, must be directly examined in the site selection problem. Also long-range geographic enrollment patterns take on added importance.

Mathematical models which could directly address all these issues would be quite complex and expensive, if not impossible, to implement. Geographic analysis, in the final reckoning, requires subjective judgments concerning interpretations placed upon the word "cost." The analytical techniques presented in the Geographic Component of the School Facility Planning System can present quantitative geographic information in such a manner that the trade-offs are clearly presented. The final decisions must be made based upon the overall goals of the school board and administration.

6.2 State of the Art

The area of mathematical programming is of rather recent development in the field of applied mathematics. Most of its development has occurred during the past twenty-five years. Many of the techniques in this area are applicable to various problems in school district planning. A brief survey of the field of mathematical programming and its application to school planning problems follows.

All mathematical programming problems involve maximizing (or minimizing) an objective function subject to certain constraints, which are usually stated as arithmetic inequalities.

Depending on the mathematical characteristics of the objective function and the constraints, these problems are given different names. Certain classes are solvable by routines that are well-known and virtually guaranteed to work. Others are only sometimes solvable. Still others remain the subject of research in the field of applied mathematics. A comprehensive, if somewhat complex. explanation of mathematical programming and its application to location analysis in the private and public sector has been prepared by Revelle, Marks, and Liebman.[1]

If the objective function is linear and all the constraints are linear, the problem is called a linear programming problem. This is the classic problem in the field of mathematical programming. A routine (the Simplex algorithm) was developed by Dr. George Dantzig in 1950. The Simplex algorithm is guaranteed to find a solution if it exists, or to indicate that no solution exists when the problem is so constructed. Though linear programs have the advantage of being readily solvable, there is the disadvantage that the real world situation must be extremely simplified, sometimes unrealistically so, in order to make the model fit.

The technique has been applied to a number of diverse problems in the area of school administration. These include the determination of optimal bus routes (Stimson and Thompson, 1972[2]); the setting of salary scales in collective bargaining negotiations (Bruno, 1969[3]); classroom location-allocation for campus planning (Graves and Thomas, 1971[4]); school time-tabling (Lawrie, 1969[5]); and the determination of school district boundaries and sites.

A more recent development in the field of applied mathematics is the subject of integer programming. In its simplest form, an integer program is formulated in exactly the same manner as a linear program. However, certain variables in the integer program are restricted from taking on any but integer (whole number) values. This restriction is analogous to the fact that one cannot send half a student to one school and half to another, or build one-third of a school.

Examination of the school area assignment problem includes two important points. The problem without racial constraints included is guaranteed to produce an integer solution. Even when racial constraints are included, experience suggests that most of the solutions are integer, and that the numbers are sufficiently large so that round-off errors do not affect the final solution. Specific uses of integer programming in this context have been designed by Heckman and Taylor, 1969[6], by Clark and Surkis, 1968[7], and by Koenigsberg, 1968.[8] The question of new facilities, however, requires a more extensive model that includes integrality of the constraints. In 1974 Fred Hall applied the techniques of integer programming to optimize the selection of new school locations.[9] Hall presented the following problem: Given that new schools are to be constructed in an existing school district, determine locations, by map grid, for these schools so that the optimal assignment of students is achieved among all possible locations for the new schools. The article goes on to mathematize the model, and provide an example for the Chicago school district.

A number of additional models have been developed which are relevant to school location-allocation problems. Typically these have data and/or computing requirements that prohibit their simple transferability between school districts.

ONPASS is an on-line pupil assignment system developed by Urban Decision Systems, Los Angeles, California.[10] This system uses machine readable student address information to allocate students to schools in a manner that achieves maximum facility utilization while at the same time keeping travel distances within reasonable bounds. Both ONPASS and a prototype version called ISPP (Interactive School Planning Procedure) use a DIME (Dual Independent Map Encoding) file. Developed by the United States Census Bureau, DIME files are available in most metropolitan areas across the country.

These models are based on systems developed for the United States Defense Civil Preparedness Agency. NAPS (Network Allocation of Population to Shelters) and more recently CACSP (Computer Assisted Community Shelter Planning) assign people to shelters, given the geographic location of the population and shelters and the street network.[11] The application of these models is obvious -- the distribution of schools and students can easily be substituted for shelters and population.

The University of Washington and the Seattle school district have created and developed another geocoding dependent system.[12] Students are assigned to the closest schools, regardless of school capacity, to project logical school boundaries and maximum needed capacity. They are also assigned to the closest schools with regard to existing school capacities and travel distance limits to identify how many students require transportation and the immediate need for portable classrooms at given locations.

Still another approach that requires a student address data base and a computer readable map which can locate students by address has been developed by Educational Coordinates in Sunnyvale, California.[13] The technique has been used to redefine attendance boundaries for the Pleasanton, California elementary school district and to calculate transportation costs for a proposed open enrollment plan in East Hartford, Connecticut.

A final system currently being used for attendance area designation is GADS (Geographic Analysis and Display System[14]). As developed by Santa Clara County's Center for Educational Planning and Center for Urban Analysis, this system allows the user to interactively experiment with alternative attendance zones, each time observing the enrollment and racial composition associated with a given configuration. A school closing model and an attendance area evaluation model for use with GADS are currently under development.

All the above models require a computer because of the time involved in making the necessary calculations. However, certain linear programming problems have a special structure that lends itself to solution by techniques that are more efficient than the more general Simplex algorithm. Such a problem is the transshipment problem in which known quantities of items are inventoried at a number of warehouses. A known demand exists at each of a number of distribution points. In addition, the cost of transportation from each warehouse to each distribution point is known. The problem is to determine how many items to ship from each warehouse to each distribution point so as to minimize the total cost of transportation.

The application of the general transshipment problem to the problem of drawing school district boundaries is obvious. The technique for solving the transshipment problem is sometimes called the stepping-stone or distribution method. It is presented in most texts on linear programming, for example, see Hadley, 1962[15] and Reinfield and Vogel, 1958.[16] The latter reference contains a particularly clear explanation of the stepping-stone method.

The transshipment problem is most efficiently solved using the stepping-stone method. Both in terms of required computer time and memory for the solution, the stepping-stone method is far superior to the standard simplex method. However, the transshipment problem is a restrictive model, in that it does not permit the introduction of additional constraints such as racial balance requirements.

6.3 School Facility Planning Approach

A linear programming approach has been selected as most applicable to the solution of attendance zone designation and site location problems. The stepping-stone method forms the basis for the Geographic Component (Chapter 5) of the manual version. The simplex method has been used in the Geographic Component (Chapter 6) for the computer version of the user's handbook. Two programs have been written that provide input and output to a previously written subroutine entitled SIMPLX.[17] BOUND is the basic program. RBOUND is a modification that incorporates minority student constraints so that attendance zones may be identified which achieve racial balance. SIMPLX solves the linear programming problem.

6.3.1 Approach Rationale

The St. Louis Research Consortium selected this approach after failing to devise any simple heuristic approach for establishing boundaries or identifying sites that would minimize student travel. The decision was made to avoid models that would require extensive data (such as a working DIME file) or extensive computer resources (such as that necessary for Hall's integer programming technique). It was also decided that the computer software must be in the public domain, even though some proprietary linear programming packages were recognized to possess more efficient, and hence, faster algorithms.

The first heuristic approach involved estimating enrollment forecasts for small geographic areas throughout the district, delineating distances from these areas to all schools, and assigning the students in each area to the nearest school. The resulting configuration of areas defined the initial attendance boundaries. The next step was to adjust the boundaries in order to achieve an acceptable, if not optimal, allocation of school capacity. As outlined in the early conceptualization of the System (Working Paper Number 2, December, 1974) this approach worked in very simple districts. However, when the number of grids and schools expanded, the boundary adjustment process became unwieldy.

A second heuristic attempt involved a graphic approach. A technique for drawing circles of a predefined radius around each school was considered. Initial boundaries were established by connecting the two points of intersection where circles overlapped for two schools. A boundary adjustment process was devised but it, too, was unsatisfactory for dealing with large school districts and large variations in the geographic distribution of student density. In the face of these difficulties, a linear programming optimizing approach was selected.

6.3.2 The Problem Formulation

Using estimates of the school age population in each of a number of small geographic areas of the district, the Geographic Component develops boundaries for the school service areas in the district. The boundaries are selected in such a way as to minimize the total physical distance of students from their assigned schools. Travel times or costs may be alternately used.

Stated precisely, the problem is to assign students to schools in such a way that the following conditions are met:

1. Each school's enrollment does not exceed its capacity;
2. Each student is assigned to a school; and
3. The total of the distances commuted daily is a minimum.

Numbers 1 and 2 are called constraints and Number 3 is called the objective.

Though the problem has now been stated precisely, it can not be solved practically. In any reasonably sized district the number of students would be so large that the problem would exceed the capacity of most existing computers. Therefore, the problem must be approximated to reduce the amount of data required.

The approximating assumption is that students who live in the same geographic sub-area or grid all live the same distance from school. This assumption has the effect of clustering the students at a point and, to that degree, is unrealistic. However, it reduces the amount of data required to solve the problem to such a degree that the inaccuracies can be tolerated. Therefore, student enrollment must be estimated in terms of rather fine, compact grids. Uniformity in the configuration of these grids greatly increases the ease of implementation as well as the accuracy of the model. The enrollment center of each grid is called its centroid.

The approximating problem is now stated mathematically. Let p_i, $i=1, 2, \ldots\ldots, m$ denote the student population in each of the m grids. Let c_j, $j=1, 2, \ldots\ldots, n$ denote the capacity of each of the n schools. And let d_{ij}, $i=1, 2, \ldots\ldots, m$, $j=1, 2, \ldots\ldots, n$. denote the distance from the centroid of the i^{th} grid to the j^{th} school. Each of the values of p_i, c_j, and d_{ij} are known or can be determined by techniques discussed in the User's Handbook.

Let x_{ij}, $i=1, 2, \ldots\ldots, n$ denote the number of students from grid i to be sent to school j. The values of x_{ij} are unknown. However, certain conditions on the x_{ij} are known. These conditions parallel those of the problem described above.

1. For any school, j, the number of students may not exceed its capacity. Symbolically $\sum_i x_{ij} \leq c_j$ for each j;
2. For any grid, i, the number of students sent from grid i to some school is equal to the population of that grid. Symbolically: $\sum_j x_{ij} = p_i$, for each i.

3. Since the product $d_{ij}\ x_{ij}$ is the total distance commuted by students from grid i to school j, $\sum_i \sum_j d_{ij} x_{ij}$ is the total distance commuted daily by students in the district. This sum is to be minimized.

In mathematical shorthand the problem is:

Find the set of values for x_{ij}, $i=1,2,\ldots,m$, $j=1,2,\ldots,n$ which minimizes $z=\sum_i \sum_j d_{ij}\ x_{ij}$ subject to:

$$\sum_i x_{ij} \leq c_j \qquad \text{for } j=1,2,\ldots,n;$$

$$\sum_j x_{ij} = p_i \qquad \text{for } i=1,2,\ldots,m;$$

$$x_{ij} \geq 0 \qquad \text{for } i=1,2,\ldots,m,\ \ j=1,2,\ldots n.$$

Such a problem is solvable (x_{ij} values can be found) using linear programming. It is assumed in the implementation that d_{ij} is non-negative for all i and j. This permits replacing the first n equality constraints above with inequality constraints of the form $\sum_j x_{ij} \geq p_i$.

6.3.3 The Problem Solution

Attendance boundaries are determined by preparing data on enrollments, school capacities, distances, and, if necessary, minority enrollment; executing the procedures; and then delineating the actual zone lines in light of street patterns and other immediate considerations. Potential sites for school closings or construction are evaluated by removing or adding a school to the initial input data; executing the procedures and calculating the total student distance or cost; and repeating the process for an alternative site. The configuration with the minimum total distance or cost is judged "best" in terms of transportation factors. Of course, this cost must then be added to operating and capital cost considerations for each site.

The stepping-stone method was selected for the manual version of the Geographic Component. The detailed instructions for carrying out this technique can be understood by most clerical employees. Experimentation with a medium-sized district (seven schools and thirty-six grids) resulted in an optimal solution in approximately ten hours. Therefore, while laborious, the required calculations are feasible for use by individuals rather than by a computer.

The stepping-stone algorithm would have been preferable to the standard simplex algorithm for incorporation into the computer version of the Geographic Component. It would have been characterized by lower core storage requirements and less execution time. Unfortunately, this algorithm is not capable of solving the student assignment problem when racial constraints are involved. Therefore, the standard simplex method was used with the recognition that more computing power and time would be required.

6.3.4 General Design of BOUND

BOUND has been programmed in Fortran and tested for school districts of varying size on an IBM 370/145 with 128K bytes of core storage. The program has three functions. First, it reads input data punched in the format described in Chapter 6 and Appendix A of the User's Handbook: Computer Version. This data specifies the number of schools, the number of grids, the capacities of the schools, the estimated grid enrollment, and the grid-school distances for each combination of grid and school. The information is recorded in a matrix. The second function of BOUND is to invoke a subroutine named SIMPLX. SIMPLX is a Fortran subroutine designed to solve the general linear programming problem. It is executed in two phases: the first phase determines a feasible solution, the second phase determines the optimal feasible solution. Phase control is provided by the formal parameter IPHS=1 or 2. Built into SIMPLX is an iteration counter designed to keep the operator informed of progress towards a solution. After each group of fifty iterations, a message is printed on the operator's console with a number called the simplex criterion. When the simplex criterion has been reduced to zero, the algorithm terminates.

The third and final function of the program BOUND is to print out the results developed by the SIMPLX subroutine. These are printed in a readily understandable format as illustrated in Appendix B of the handbook.

The operation of BOUND can be further explained by examining the structure of the matrix it builds for a sample problem, where there are five grids (i.e., $m=5$) and three schools (i.e., $n=3$).

Figure 6-1 indicates the general form of the array. This array consists of zeroes (0) and ones (1) except in two locations. The first is the rightmost column where the student population per grid (p_i) and the capacity of each school (c_j) are entered as shown. The other is the partial diagonal where negative ones (-1) have been entered. These values account for the artificial variables that are introduced in performing the Phase I, SIMPLX algorithm. A detailed explanation of the role of artificial variables can be found in the Theory of Linear Programming.[18]

FIGURE 6-1 BOUND MATRIX

$$\begin{array}{c|ccc|ccc|ccc|ccc|ccc|ccc|ccccc|ccccc|c}
 & \multicolumn{15}{c}{mn} & \multicolumn{3}{c}{n} & \multicolumn{5}{c}{m} & \multicolumn{5}{c}{m} & \\
\hline
 &1&1&1&&&&&&&&&&&&&&&&-1&&&&&1&&&&&P_1 \\
 &&&&1&1&1&&&&&&&&&&&&&&-1&&&&&1&&&&P_2 \\
m&&&&&&&1&1&1&&&&&&&&&&&&-1&&&&&1&&&P_3 \\
 &&&&&&&&&&1&1&1&&&&&&&&&&-1&&&&&1&&P_4 \\
 &&&&&&&&&&&&&1&1&1&&&&&&&&-1&&&&&1&P_5 \\
\hline
 &1&&&1&&&1&&&1&&&1&&&1&&&&&&&&&&&&&C_1 \\
n&&1&&&1&&&1&&&1&&&1&&&1&&&&&&&&&&&&C_2 \\
 &&&1&&&1&&&1&&&1&&&1&&&1&&&&&&&&&&&C_3
\end{array}$$

The two groups of rows correspond to the two classes of constraints in the original problem. The first m rows correspond to the population constraints of the m grids. The last n rows correspond to the capacity constraints of the n schools. The ones in the first mn columns represent the coefficients of x_{ij} in the sums of the constraints. The remaining ones and negative ones in the array account for slack or artificial variables as needed. The total size of the array is $m+n+1$ rows times $mn+n+2m+1$ columns. An extra row not shown in the figure is included for the cost function.

Once the array has been built, BOUND calls SIMPLX with the parameter IPHS=1. A Phase I calculation is performed and the artificial variables are eliminated according to standard Phase I techniques. Upon return from Phase I, SIMPLX is called immediately with IPHS=2. This time the cost function is minimized and the optimal solution is found. BOUND then prints out the non-zero variables of the matrix in a readable format.

6.8.5 General Design of RBOUND

Those districts interested in establishing attendance zones or selecting school sites that will promote racial balance need to consider additional constraints. The previous model may be extended to include these additional constraints, provided additional data is available. Suppose that B represents the percent minority in the district as a whole and that v is the maximum permissible variation from B for any school in the district. Suppose further that b_i, $i=1,2,\ldots,m$ is the percent minority in each of the m grids.

Since $\sum_i x_{ij}$ is the number of students in school j, the number of minority students in school j must be between the two limits: $(B-V)\sum_i x_{ij}$ and $(B+V)\sum_i x_{ij}$.

Since b_i is the percent minority in grid i, $b_i x_{ij}$ is the number of minority students from grid i who will attend school j. Summing over all grids $\sum_i b_i x_{ij}$ is the number of minority students attending school j. Since this quantity must fall between the limits stated above, the two following inequalities must hold for each school: $\sum_i b_i x_{ij} \geq (B-V) \sum_i x_{ij}$ and $\sum_i b_i x_{ij} \leq (B+V) \sum_i x_{ij}$.

RBOUND is a modification to BOUND that minimizes transportation distance subject to BOUND's basic constraints, and the additional constraints that no school's minority enrollment fall below or exceed prescribed limits. These additional constraints have the following general form: $\sum_i (B-v-b_i)\, x_{ij} \leq 0$ and $\sum_i (b_i-B-v)\, x_{ij} \leq 0$ for $j=1,2,\ldots n$ where $r_i = B-v-b_i$ and $S_i = b_i-B-v$.

RBOUND is organized in the same way as BOUND, except for the revised structure of the matrix. The additional constraints are added to the array as 2n rows. The slack variables for these sets of constraints are inserted from columns mn+n through mn+3n, moving the remaining columns of the original array 2n positions to the right. These modifications to the original array are shown in Figure 6-2.

FIGURE 6–2 RBOUND MATRIX

$$\begin{array}{c|ccc|ccc|ccc|ccc|ccc|ccc|cccccc|ccccc|ccccc|c}
 & mn & & & & & & & & & & & & & & & n & & & 2n & & & & & & m & & & & & m & & & & & \\
\hline
m & 1 & 1 & 1 & & & & & & & & & & & & & & & & & & & & & & -1 & & & & & 1 & & & & & P_1 \\
 & & & & 1 & 1 & 1 & & & & & & & & & & & & & & & & & & & & -1 & & & & & 1 & & & & P_2 \\
 & & & & & & & 1 & 1 & 1 & & & & & & & & & & & & & & & & & & -1 & & & & & 1 & & & P_3 \\
 & & & & & & & & & & 1 & 1 & 1 & & & & & & & & & & & & & & & & -1 & & & & & 1 & & P_4 \\
 & & & & & & & & & & & & & 1 & 1 & 1 & & & & & & & & & & & & & & -1 & & & & & 1 & P_5 \\
\hline
n & 1 & & & 1 & & & 1 & & & 1 & & & 1 & & & 1 & & & & & & & & & & & & & & & & & & & C_1 \\
 & & 1 & & & 1 & & & 1 & & & 1 & & & 1 & & & 1 & & & & & & & & & & & & & & & & & & C_2 \\
 & & & 1 & & & 1 & & & 1 & & & 1 & & & 1 & & & 1 & & & & & & & & & & & & & & & & & C_3 \\
\hline
2n & r_1 & & & r_2 & & & r_3 & & & r_4 & & & r_5 & & & & & & 1 & & & & & & & & & & & & & & & & 0 \\
 & & r_1 & & & r_2 & & & r_3 & & & r_4 & & & r_5 & & & & & & 1 & & & & & & & & & & & & & & & 0 \\
 & & & r_1 & & & r_2 & & & r_3 & & & r_4 & & & r_5 & & & & & & 1 & & & & & & & & & & & & & & 0 \\
 & s_1 & & & s_2 & & & s_3 & & & s_4 & & & s_5 & & & & & & & & & 1 & & & & & & & & & & & & & 0 \\
 & & s_1 & & & s_2 & & & s_3 & & & s_4 & & & s_5 & & & & & & & & & 1 & & & & & & & & & & & & 0 \\
 & & & s_1 & & & s_2 & & & s_3 & & & s_4 & & & s_5 & & & & & & & & & 1 & & & & & & & & & & & 0
\end{array}$$

The total size of the above array is m+3n+1 rows by mn+3n+2m+1 columns. Again, an extra row is included for the cost function that has not been illustrated. Once the array has been constructed, RBOUND's remaining operations are similar to those in BOUND.

The core requirements obviously grow very rapidly as the number of grids and schools in the district increase. As the matrix expands, it will be necessary to reserve more core storage. This may be accomplished by modifying the "dimension statement" as outlined in Appendix B of the User's Handbook.

6.3.6 Conclusion

Most school districts have traditionally established attendance zones and selected sites for the construction or closing of facilities using an intuitive approach. For many districts this technique may suffice. Other districts with a good data base and sufficient money and time may want to explore one of the relatively sophisticated approaches identified in Section 6.2.

The linear programming approach presented in the School Facility Planning System appears to represent a good compromise between these two alternatives. Further practical experience with this technique will, in fact, reveal whether this is true. This testing should consider a variety of districts in terms of size, available data, and problem situations. As suggested in the analysis section of the Geographic Component, many specific constraints can be examined, such as the desire to equalize the distribution of excess school capacity, or prohibit a given route to a school. Other policies such as the use of magnet schools or resource centers may not be susceptible to analysis with the current package.

A practical deficiency that must be overcome is the amount of computer time required, especially when RBOUND is used. Continued modifications to the program may be necessary to accelerate the convergence to a feasible solution The matrices involved are extremely sparse. Storage compaction techniques could reduce the storage requirements and execution time drastically. More fundamental research would involve an attempt to modify and program the stepping-stone algorithm so that it would permit the use of racial constraints. Also, an evaluation of BOUND and RBOUND (which are free, but relatively inefficient) should be made in comparison with the more expensive, but more efficient, proprietary software in the possession of various service bureaus.

Finally, continued research into definitions of cost is appropriate, especially in dealing with the site selection problem. Procedures must be better developed for conducting the trade-off analysis between more school buses, more facilities, and longer walks by children to school. Users that develop insight in this area are encouraged to share their findings with other users of the School Facility Planning System.

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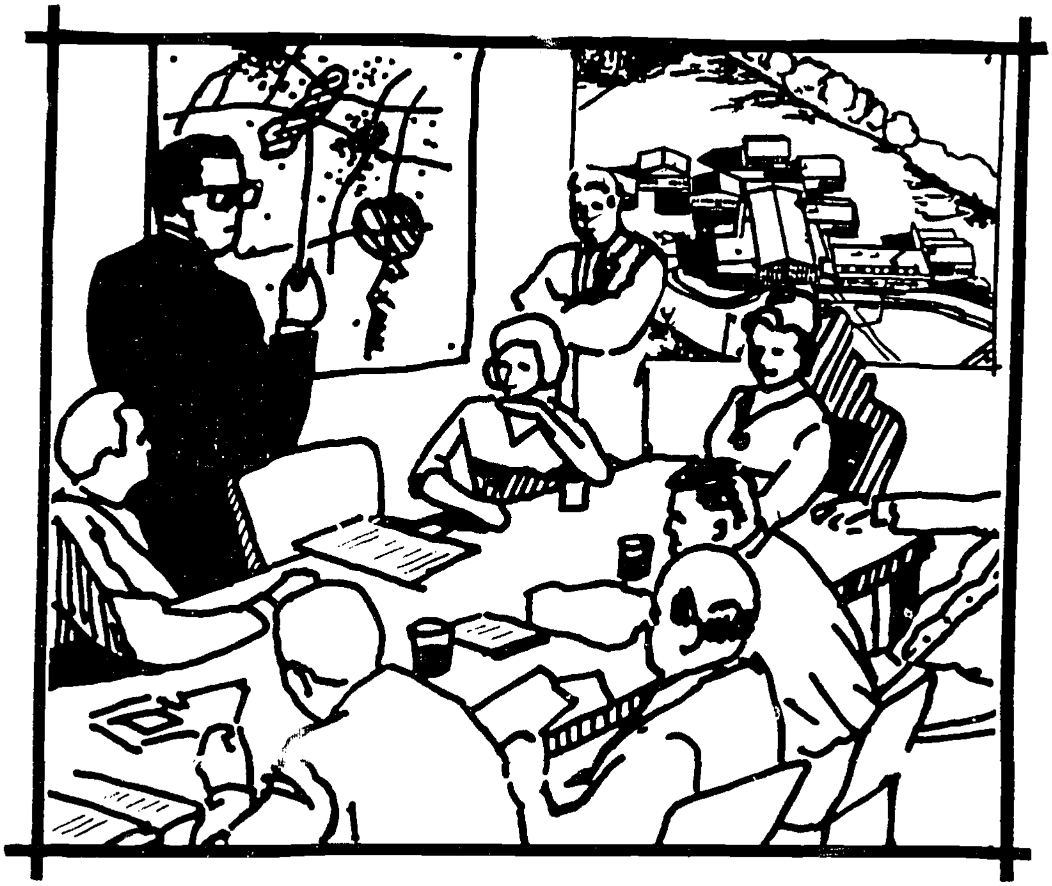


Chapter 7: Systems Utilitization

The previous four chapters have discussed the School Facility Planning System components in broad terms. The actual instructions associated with the specific techniques are, of course, outlined in the respective versions of the user's handbook. The purpose of this chapter is to demonstrate how the System can be used in a variety of different planning situations. The chapter is purposely short. The emphasis is on considerations that might be made, difficulties encountered, and shortcuts adopted. The chapter is designed to suggest the versatility and characteristics of the School Facility Planning System. This chapter in no way replaces the requirements that the serious user must read and experiment with in order to become familiar with all phases of the System.

7.1 Initial Activity

Facility planning problems come in many forms. Sometimes the problem is narrow and immediate; e.g., where can we house the additional junior high students that we didn't expect, or how can we afford to repair the furnace? Other times the problem is much [illegible]ler and long range; e.g., what facility requirements can we expect over the next five [illegible] and what fiscal options do we have to pay for them? Often the immediate problem [illegible] out to be only a symptom of a more fundamental situation within the schools and community.

Chapter 6, Project Organization, suggests that in all but the most trivial cases, a short written statement or guide should be prepared that summarizes the problem, the available resources, and the general community situation. This guide would form the initial attempt to answer the questions that must be answered as part of any planning effort. Edward Green has categorized these questions as follows:[1]

A. Where Are You? What is the nature of the activity, organization or business in which you are engaged? What is the larger environment (the legislation, governmental policies, and community attitudes) in which you operate? What can be accomplished within this environment?

B. Where Do You Want to Go? What long-range goals and tangible objectives does the school district want to achieve? On what assumptions are these goals and objectives based over which the district has no control?

C. How Do You Want to Get There? What general strategies and policies should the district consider? What specific problems and procedures might be used to implement them?

D. When Do You Want to Arrive? What schedule should be established? What priorities should be assigned among competing programs?

E. How Much Will It Cost? What financial resources will be necessary and when, to support the facility plan? What policies and assumptions are the fiscal projections predicated upon?

The final answers to these six questions will be possible only at that point at which the superintendent and school board are ready to select a plan from among the available alternatives. However, consideration of these questions should begin from the start. Based on the initial answers, a research team can be assembled, responsibilities assigned, and a schedule established.

The research team, be it one individual or a large committee, must make tentative decisions at an early date with regard to four issues:

A. The Manual or Computer-Based Version. Both approaches have strengths and drawbacks as discussed in Chapter 2 of the computer version. The computer-based version probably involves more initial investment in time to make the System operational. It has the flexibility and speed to justify this investment when a district anticipates a major annual planning function. A compromise approach that may develop over time would involve selecting the computer-based approach, but sending the desired test data to a remote facility, such as the Council of Educational Facility Planners, where the System has been installed. One or two major school districts within a metropolitan area might also provide this service to neighboring school districts.

B. The Planning Horizon. The length of the planning period will be important in deciding what forecasting techniques to employ. In turn, it should be influenced by the nature and magnitude of the planning problem. As noted in Chapter 1 of each handbook, two dates are actually important, the final year of the planning period (the planning horizon) and the year on which the decisions will focus. Population and fiscal forecasts must be discounted like all other projections. There is much more certainty regarding the early rather than later, years of the forecast. Furthermore, providing facilities that will satisfy the community in the next several years is more important than satisfying the community twenty years from now. In summary, the user may want to make projections for a twenty or thirty year time frame, but plan facilities geared to the student population in a much shorter time frame.

C. System Components. The chart in Chapter 1 of the handbook emphasizes the interdependence, but also the independence, of the four components. All may be used in concert, but one or two may be selected if only they are required. Each component requires certain data, of course, but it may be supplied from an independent source, as well as by the calculations of another component. The desirability of using each component must be examined in the context of the district's problem, available data, and available time.

D. Level of Analysis. Each component can be used at a detailed or a general level. Enrollment forecasts can be made for total enrollment on a district-wide basis or by grade on a sub-attendance area basis. Space requirements can be determined for all junior high students, for the students in a particular school, or for just the students expected to enroll in industrial arts or some other course. Operating and capital expenditures can be developed on a district-wide or single school basis.

The level of analysis will be selected in light of the problem. In general the longer the planning period, the more general should be the focus. Some districts may want detailed projections for the next five years, and more general projections for the subsequent fifteen or twenty years.

7.2 Enrollment Analysis

The Enrollment Component has been used in a series of district situations. As emphasized in Chapter 3 and the handbooks, the technique(s) should be selected in light of the community's demographic patterns and available data. Consideration of several techniques will typically be favored over dependence on just one.

The variation produced by different techniques is dramatic. Figure 7-1 illustrates a series of alternative time series extrapolations based on the same historical data for a rapidly growing school district. The district grew from 8,492 average daily attendance in 1965 to 21,600 in 1974.

FIGURE 7—1 ALTERNATIVE TIME SERIES FORECASTS

	1980	1985	1991
1. Linear Projection	31,977	39,424	48,360
2. Exponential Projection	45,127	74,701	136,770
3. Modified Exponential Projection	24,172	24,970	25,353
4. Modified Exponential Projection (with asymptote = 24,900)	23,823	24,471	24,758
5. Logistics Projection	22,937	23,071	23,094
6. Logistics Projection (with asymptote = 26,000)	25,092	25,746	25,946
7. Gompertz Projection*	23,667	24,050	24,166
8. Gompertz Projection* (with asymptote = 24,900)	24,140	24,664	24,843

* The Gompertz projections were made on the same historical data set, but only through 1973 when there were 21,053 students.

The dangers of mindless extrapolation are apparent. Without knowing the district's characteristics, it is not possible to say which of the time trend projections are most reasonable. Some, such as the exponential curve, are likely to be unreasonable in a long-range forecasting situation. The use of a curvilinear technique appears more acceptable in a long-range situation, especially since the user can specify an approximate holding capacity (asymptote) which the extrapolation should not exceed. None of the extrapolation techniques can actually shift the direction of the forecast. Thus, a forecast of continued growth (or decline) leveling off, and then actual decline (or growth) would have to be made using one of the other forecasting techniques.

Time series techniques have another characteristic that may cause concern in very short-range forecasting situations. Suppose that the historical data has fluctuated so that in certain years there was a rise or fall from the previous year running counter to the overall trend. In these situations the first, and possibly second year, of the forecast may be below or above what would be reasonably expected. For example, in the illustration above even though a least square linear projection anticipates a climb from 21.600 in 1974 to 31,977 in 1980 (an average of 1,730 per year), the 1975 projection might be considerably below 23,330 because of the distribution of the historical data. In such short-range situations a cohort survival projection might provide more acceptable figures.

The ratio technique and dwelling unit multiplier technique are alike in many respects. Unlike the time series techniques, the ratio and dwelling unit approach depend upon accurate independently derived forecasts, projected students or population for a larger area in the first case, and projected dwellings by type in the second. If these independent forecasts are poor, the enrollment forecasts will suffer. The techniques also can fail if the ratios applied against the independent forecasts are inaccurate. In the first technique the ratio between the district's enrollments and the larger area's population must be estimated. In the second case the ratio of public school students to each dwelling type must be calculated.

The ability to vary the ratios means that the projected number of students will not necessarily be positively correlated with the independent variable projection. For example, a small, slowly growing district has projected that its single family housing stock will increase by 260 units, and its multiple family housing stock will increase by 115 units during the next five years. However, the public school student yield is expected to decline in this aging community from 1.83 to 1.54 for single family units and .19 to .04 for multiple family units. (The new apartments are expected to be primarily small units for elderly residents.) Therefore, even though the total housing stock will increase from 6,989 to 7,363, it is projected that the district's student enrollment will decrease from 11,986 to 11,133 by 1980.

7.3 Facility Analysis

The Facility Component determines space requirements in light of enrollment projections and school district standards. It may also be used to evaluate the impact of alternative school district options. The effect of changing one or more standards or of adding or deleting physical space can be examined for each year of the planning horizon.

The Component can be used to analyze very broad or very narrow space requirements as determined by the user. Policy variables that may be manipulated by a district include:

Subject Area — This may be defined to include all courses in a given school, or in all schools; only one course, or a grouping of courses, with similar space requirement characteristics.

Course Enrollment — The number of students that sign up for a subject area (which is defined to be one or a grouping of courses) will fluctuate with student tastes, state legislation (e.g., requirements that all students take state history or gymnasium, etc.) and school board policy.

Course Periods Per Week — Many courses meet daily or five times per week. Others meet two or three times per week. When a subject area is defined to include both kinds of courses, the average number of periods per course is likely to be a number such as 4.73.

Number of Periods Per Day — Most schools typically have five or six periods per day. Those on staggered or double sessions would have more.

Number of Days Per Week — Most schools typically are in session five days per week. A work-study program could conceivably be different. Note that this variable and the one above are combined into one variable — periods per week — in the computer version.

Utilization Rate — Teaching space may be used for study halls, extracurricular activities, storage, and many additional activities. The utilization rate is a factor that can be modified to vary the number of classrooms available for such flexible uses.

Existing Teaching Stations or Square Feet — The number of rooms or amount of space considered adequate for teaching may be adjusted by adding space (e.g., potential facility construction, rehabilitation, or leasing) or by deleting space (e.g., potential facility closing).

Desired Students Per Teaching Station — The school administration may consider a variety of alternative standards as to the desired students per room.

Desired Square Feet Per Student — Those districts that conduct analysis in square feet must prescribe a standard which can be applied.

Required Daily Course Load Per Teacher — This variable is necessary to determine the required number of teachers per subject area. In most instances required classrooms will be different from required teachers because teachers are usually not available for every period of the day.

The Facility Component has been executed in a variety of hypothetical settings. The variation in the number of students that can be housed in the same physical space is impressive, especially when the district is willing to consider double sessions, a twelve-month school year, and other major policy shifts. Figure 7-2 indicates alternative teaching space requirements for a 1980 projected junior high enrollment of 2,731. In Figure 7-3 the subject area has been defined to include just business courses. It is projected that about eleven percent (1,639 ÷ 13,655) of all course enrollment will be devoted to business subjects in 1980. In this instance, space considered suitable for business courses has been measured in square feet, rather than in classrooms.

FIGURE 7—2 ALTERNATIVE TEACHING SPACE REQUIREMENTS — 1980

Options	Required T.S.	Subject Area Enrollment	Desired Students Per T.S.	Course Periods Per Week	Periods Per Day	Days Per Week	Utilization Rate	Existing T.S.
A	106	13,655	24	5	6	5	.9	95
B	75	13,655	24	5	8	5	.9	95
C	98	13,655	26	5	6	5	.9	95
D	100	13,655	24	5	6	5	.95	95
E	91	11,749	24	5	6	5	.9	95

In Figure 7-2, Option A utilizes the existing school district standards of six class periods per day, five days per week, with an average class size of twenty-four students per class and a utilization rate of ninety percent. A deficit of eleven teaching stations is projected for 1980 using these existing standards and facilities. In Option B, the school district examined a modified staggered session policy which would expand the number of class periods per day to eight. This would increase the available class periods per week by one-third, thereby replacing the projected deficit with an expected excess of twenty stations. A third alternative is to vary the average number of students per class. Option C reflects the consideration of twenty-six students per teaching station to derive a projected need for ninety-eight teaching stations. Option D concentrates on the utilization rate adopted by the school district. If class scheduling could be modified to use the existing classrooms at a rate of .95, then the required number of teaching stations would be 100. A final alternative considered by the school district would be the initiation of a work-study program, whereby a certain percentage of the students were off-campus for one or more periods of the day. This policy would reduce the number of required teaching stations. In this situation, the assumption was made that one-third of the students would participate in the work-study program. As a result, only ninety-one teaching stations would be necessary.

The same kinds of options are available to determine space requirements for more narrowly defined subject areas such as business courses. In Figure 7-3, existing space considered suitable for business courses has been measured in terms of square feet. The district's standard for square feet per student replaces desired students per teaching station in the calculations. Option A indicates that a considerable space deficit is likely in 1980, given existing standards and facilities and the projected business course enrollment. Staggered sessions (Option B), reduced square feet per student (Option C), and a higher utilization rate (Option D) are possible alternatives that would reduce the size of the deficit. Option E simply examines how the situation might be altered if additional space were devoted to business courses. In this case, 1,650 square feet of space is proposed for conversion from academic to business use in order to reduce the space deficit. Each option in the above examples allowed only one policy or standard to vary. Obviously, two or more variables could be changed at the same time. In testing alternative plans, the district must determine which policies can vary and the degree of variance which would be acceptable to the community as a whole.

FIGURE 7—3 ALTERNATIVE TEACHING SPACE REQUIREMENTS—BUSINESS 1980

Options	Required Square Feet	Subject Area Enrollment	Square Feet Per Student	Periods Per Course	Periods Per Day	Days Per Week	Utilization Rate	Existing Square Feet
A	6,336	1,639	22	5	6	5	.95	4,400
B	4,752	1,639	22	5	8	5	.95	4,400
C	5,760	1,639	20	5	6	5	.95	4,400
D	6,138	1,639	22	5	6	5	.98	4,400
E	6,336	1,639	22	5	6	5	.95	6,050

7.4 Fiscal Analysis

The Fiscal Component addresses perhaps the most complex element of school facility planning. The Facility and Geographic Components involve complicated calculations, but relatively little uncertainty. They essentially translate one set of projected conditions into a second set. Projected students are translated into required space (Facility Component) and expected "transportation costs" (Geographic Component). The Enrollment Component involves substantially more uncertainty, but because demographic trends are usually gradual, historic data often serves as a useful guide to the future. Fiscal trends are substantially more erratic.

No analytical technique can accurately predict the impact of inflation, the teacher's union, the local electorate, or state representatives. Judgements regarding next year's effect of these and other forces on the school budget are extremely difficult, let alone the effect over a ten-or twenty-year planning period. Therefore, the Fiscal Component exists primarily to explore the probable impact of alternative conditions. The user is helped in understanding what would happen if a bond issue was floated, the tax rate was cut, the legislature changed its allocation formula, or if any of numerous other contingencies materialized.

It will be particularly necessary to tailor this component to specific district situations. The instructions for calculating net bonding capacity can be disregarded by those districts that foresee little need for new debt or that are not restricted by debt limitations. Similarly, building costs forecasts and selected revenue or expenditure forecasts will be inappropriate in some areas. Some users will want to consider redefining the revenue and expenditure categories so that they coincide with their district's set of accounts.

The model is more open-ended regarding specific forecasting techniques in the Fiscal Component than in the other components. As noted in Chapter 5, many expenditure categories can be projected as a function of an independent forecast of students, teacher salaries, or physical space. Experimentation within a given district will be necessary to determine which of these, or perhaps other independent variables, has the most predictive power. In revenue forecasting situations, users are encouraged to apply the exact local and state formulas which impact their community, rather than the general approaches outlined in the handbooks.

The handbooks' approach to inflation is to recommend that costs and revenues be increased in light of expected or hypothetical inflation rates. Generally an exponential, rather than linear, curve should be used in forecasting situations. Some users may want to perform all calculations in constant dollars, and then apply an inflation rate. This would involve the following kind of process:

A. Discount historical expenditures by determining the inflation rate for past years, selecting 100 as the index for the current year, and subtracting the rate from the index to determine the previous year's index.

Example:

	1973	1974	1975
Inflation Rates	.06	.08	.07
Index	.85	.93	100

Calculate deflated dollars by dividing the index into the actual expenditures for previous years.

Example:

	1973	1974	1975
Actual Expenditures (1,000)	583	675	690
Deflated Expenditures (1,000)	686	726	690

675 ÷ .93

583 ÷ .85

B. Project future expenditures in constant dollars.

C. Multiply the projected expenditures by an inflation rate of the user's choice.

Other users might want to consider a short cut for dealing with inflation that involved "inflating students." The formula would take the form: students x $(1+r)^n$ where r was the assumed inflation rate and n the number of years into the future for which the projection was being made. When multiplied times a unit cost per child figure, this number would yield projected expenditures as a function of projected students. The more traditional approach to achieve the same goal would require inflating the unit cost per student figure, and then multiplying times projected students.

Much of the relevant fiscal analysis cannot be conducted in a predefined modeling framework. Analysis of potential savings inherent in closing or constructing one school rather than another must be examined on a case-by-case basis. In the construction situation, economies of scale, the cost of land, the cost of materials, and numerous other factors must be examined. In the school closing situation, utility costs, resale opportunities, transportation insurance, and similar concerns must be examined. Most of this kind of detailed analysis is not especially assisted by the School Facility Planning System except as a means of recording and comparing the findings associated with different alternatives.

7.5 Geographic Analysis

The Geographic Component may be used to redefine attendance zones or to examine the transportation implications of various sites for construction or closing. It has been tested for several small and medium sized districts. The manual version has been found to be potentially useful, though laborious for any but the smallest districts. The computer version, especially RBOUND, has not had sufficient testing to establish its relevance. The amount of computer time required to reach the optimal solution is as yet an unresolved concern.

A summation of one hypothetical problem analyzed using the manual "stepping stone approach" follows.

Experiencing a substantial drop in enrollment and revenue, the school board decided to "mothball" one elementary school indefinitely in an effort to cut operating costs. The board was inclined to close elementary school Number 1 because of its age and inefficient heating plant. However, it wanted to explore all elementary school closing options in an effort to decrease costs as much as possible and to minimize student travel time. Historical operating costs were available for each school; thus these savings could be readily determined for each alternative site. The other major factor to be considered was total student travel distance given each school closing alternative.

Following the procedures outlined in Chapter 5 of the User's Handbook: Manual Version, a distance matrix was prepared indicating the estimated students in each grid and the distance from the centroid of that grid to each school (see Figure 7-4). Then total student travel distance was calculated for each alternative school closing. In the first alternative, elementary school Number 1 was dropped from the matrix and the steps completed with new enrollment projections per grid (see Figure 7-5). The grid enrollments were assigned to the closest school resulting in school Number 2 having an excess capacity of seventy-five and school Number 3 an excess capacity of twenty-five. Values for blank squares were calculated. They were all positive, indicating that the optimal solution for this matrix had been reached on the first iteration. Using the same procedures, blank square values were calculated for each of the other two school closing alternatives (see Figures 7-6, 7-7, and 7-8).

Closing school Number 1, the school board's initial choice, would result in the highest distance traveled by all students (1,900). Closing school Number 3 would lower the total travel distance to 1,425. However, the most "efficient" alternative would be to close school Number 2, thereby resulting in a total travel distance of 1,175. Closing school Number 2 would also produce the most efficient use of buildings in terms of excess capacity. There would be no excess capacity associated with this alternative; whereas closing school Number 3 would result in an excess capacity of 50 and closing school Number 1 would produce an excess capacity of 100.

Based on a number of factors including operating cost, age, safety of structure, and total travel distance, the school board decided to close school Number 3. In short, the board felt that closing school Number 2 would leave no room for expansion if enrollment suddenly increased in the future. Although closing school Number 1 would yield the greatest savings in operating cost, the district was not willing to accept the hazards and costs associated with this alternative's increased travel distance. Total student travel distance is only one criterion that should be considered in potential school closings. The most efficient or economical alternative may not be the wisest or safest choice.

Note:

1. Edward J. Green, Work Book for Corporate Planning, Planning Dynamics Corporation, Pittsburgh, Pennsylvania, 1970.

FIGURE 7–4 ORIGINAL SCHOOL DISTANCE MATRIX

	SCHOOLS			
GRIDS	1	2	3	ENROLLMENT
1	5	3	4	100
2	2	6	3	200
3	4	2	1	100
4	1	4	5	300
5	4	3	2	200
(6)	0	0	0	
	300	400	35C	
	CAPACITY			

FIGURE 7–5
SCHOOL CLOSING NO. 1 ALTERNATIVE

	SCHOOLS		
GRIDS	2	3	ENROLLMENT
1	3 (75)	D 4	75
2	A 5	3 (100)	100
3	B 2	1 (75)	75
4	4 (250)	E 5	250
5	C 3	2 (150)	150
(6)	0 (75)	0 (25)	
	400	350	1900
	CAPACITY		

FIGURE 7–6
SCHOOL CLOSING NO. 3 ALTERNATIVE

	SCHOOLS		
GRIDS	1	2	ENROLLMENT
1	A 5	4 (75)	(75)
2	2 (100)	E 5	(100)
3	B 4	2 (75)	75
4	1 (200)	4 (50)	(250)
5	C 4	3 (150)	150
(6)	D 0	0 (50)	
	300	400	1425
	CAPACITY		

FIGURE 7–7
SCHOOL CLOSING NO. 2 ALTERNATIVE

	SCHOOLS		
GRIDS	1	3	ENROLLMENT
1	A 5	4 (75)	75
2	2 (50)	3 (50)	100
3	B 4	1 (75)	75
4	1 (250)	D 5	250
5	C 4	2 (150)	150
	300	350	1175
	CAPACITY		

FIGURE 7–8 BLANK SQUARES' VALUE CALCULATION FOR EACH ALTERNATIVE SCHOOL CLOSING

ALTERNATIVE 1

A. +5-0+0-3=+2

B. +2-0+0-1=+1

C. +3-0+0-2=+1

D. +4-3+0-0=+1

E. +5-0+0-3=+2

ALTERNATIVE 3

A. +5-1+4-3=+5

B. +4-1+4-2=+5

C. +4-3+4-1=+5

D. +0-1+4-0=+3

E. +5-4+1-2=0

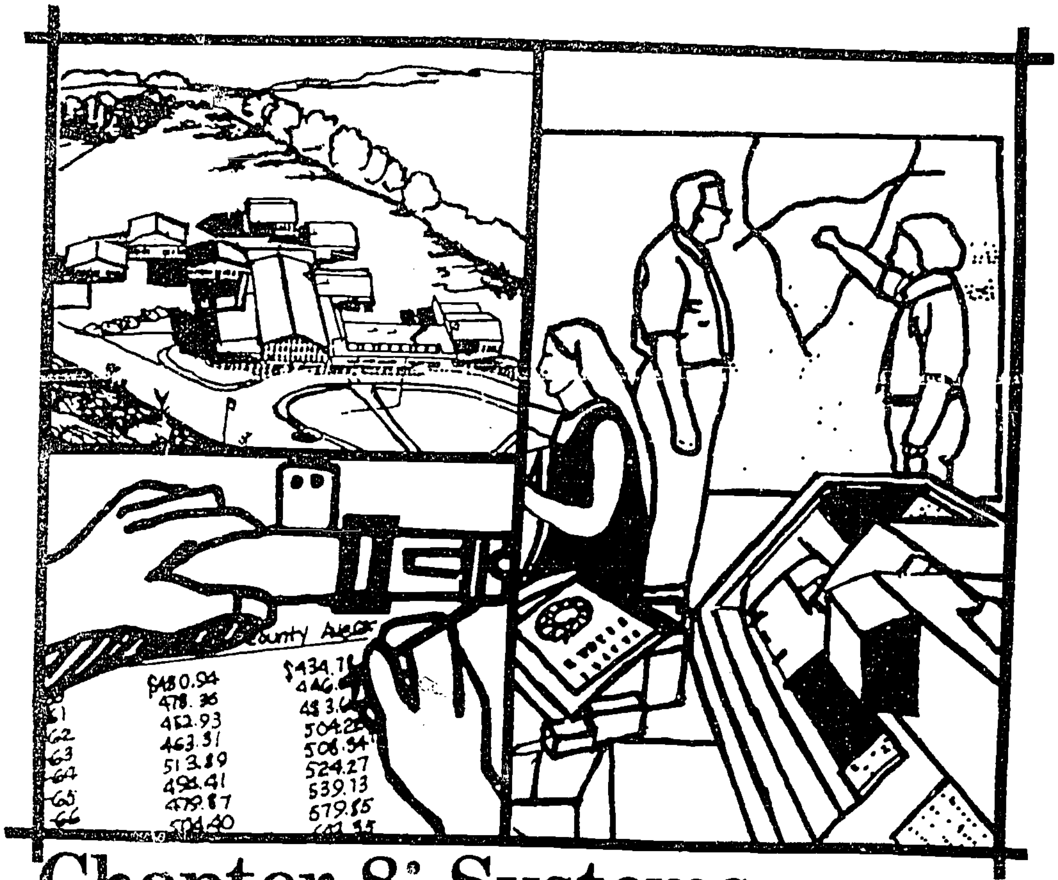
ALTERNATIVE 2

A. +5-2+3-4=+2

B. +4-2+3-1=+4

C. +4-2+3-2=+3

D. +5-3+2-1=+3



Chapter 8: Systems Evaluation

This chapter presents a summary of responses to a preliminary draft of the School Facility Planning System. It is based on information received during several evaluation sessions and on a questionnaire distributed to public school administrators. The chapter is a composite of the responses and recommendations offered by these sources.

8.1 Introduction

The importance of a detailed evaluation was recognized as fundamental to the successful development of a long-range capital planning and budgeting system. Phase Six of the grant proposal was explicitly designed to evaluate and test both the manual and computer-based versions. In the Spring of 1975 it became clear that a full scale evaluation of both new systems could not be conducted within the scope of the project. The decision was made to concentrate on the manual version, and to limit testing of the computer-version to review by the consortium members alone. Unfortunately, time and budget limitations required that the manual version be critiqued quickly by a relatively small number of individuals. Of course, the continuing review by a large Project Review Committee, the consortium members, and, to a lesser degree, other NSF supported research teams[1] insured an evaluation process throughout the project.

8.2 The Ongoing Evaluation Process

Throughout the process of developing the School Facility Planning System, the consortium members solicited and incorporated the ideas of many professional consultants, teachers, and administrators. A particularly valuable source of ideas was the Project Review Committee which consisted of school officials, professional planners, and university faculty.

Two questionnaires, one distributed to school districts across the nation and one distributed to state offices of education, and interviews with twenty St. Louis area school administrators provided much of the preliminary information. Although many of the superintendents appeared enthusiastic about the forthcoming project, some were skeptical because of difficulties arising from the unique characteristics in each school district.

Project Review Committee meetings in October, 1974, and April, 1975, reviewed development proposals and draft documentation for the School Facility Planning System. It was reported that the usefulness of such a system depended upon a complex number of factors including: accurate short-range and acceptable long-range enrollment projections; future construction and operating expense projections as related to facility needs; analysis of existing school plants using professional and community leaders; criteria and standards for ever changing educational programs; the economic, social, and political climate within the school district's community; and the technical competence of the educational administrators. The need for an approach which explicitly incorporated the concept of uncertainty and described the System in terms that school administrators could comprehend was readily agreed upon. The desire to have a planning system which would be comprehensive and yet modular with regard to organization was also expressed.

At the final meeting in St. Louis the Project Review Committee examined a draft of the proposed system in order to offer recommendations prior to field testing. Concern that the final draft be sensitive to the varying levels of sophistication among school superintendents, without being prescriptive or verbose, was noted. It was suggested that, except for certain data requirements, the System need not have a sequential or linear relationship between components. The theme of uncertainty was recognized as needing additional emphasis in this version of the User's Handbook.

At this meeting the computer version of the School Facility Planning System was also discussed. Suggestions focused upon an examination of enrollment forecasting alternatives and computer methods for solving problems particular to specific public school systems. The importance of testing both versions of the System for a variety of school district situations was emphasized.

8.3 Final Evaluation—Manual Version

Evaluation of the final draft of the School Facility Planning System was the responsibility of the Department of Education, St. Louis University. A committee of one faculty member and two graduate students was formed to initiate this process. It was agreed that examination of the System by graduate students in school administration, the development of a questionnaire to accompany drafts of the documentation to a sample of public school administrators, and tabulation of the responses would result in objective feedback about the model.

Ten graduate students in school administration examined the proposed model in April, 1975. Their purpose was twofold: To review the draft for deficiencies in the computational formulas and writing style, and to submit items for inclusion in the evaluation questionnaire for school administrators. During the discussion session, which was taped, several chapters were reviewed with Enrollment and Facility Components generating the majority of ideas. The method for computing facility needs using a measure of square footage was questioned for [illegible]. Further explanation of terms such as "utilization factor" and "basic capacity" was requested. General agreement was lacking as to who would complete the data collection assignments necessary for school planning. A simple presentation was recognized as more likely to be read by busy school personnel. The suggestions were presented to the consortium with the recommendation that they be incorporated into the final draft.

8.3.1 Evaluation Design

An evaluation questionnaire was developed with the assistance of graduate students and the Evaluation Committee. After examining the specifications of the proposed system, items were written by students of school administration for each of the seven chapters. Items were reviewed for their consistency in addressing the face validity and reliability of the techniques, as well as the clarity of the instructions and ease of implementation for each component. The chapters were examined so that sets of independent items related to specific content were included in the questionnaire. Since the need to ask a limited number of questions was recognized, between ten and twenty-six statements for each chapter were agreed upon. Responses to each statement were requested on a continuum of one to seven, ranging from "completely disagree" to "completely agree." Additional space was allowed for comments. The evaluation instrument was then reviewed by members of the County Department of Planning where minor changes to several items were completed.

8.3.2 Sample Population

The revised draft of the School Facility Planning System and the evaluation questionnaire were distributed during August, 1975. Packages consisting of the document, a cover letter, directions for completing the evaluation, the questionnaire, and a return envelope were mailed to twenty-five school superintendents and five university persons or Project Review Committee members. Fourteen school districts were selected within metropolitan St. Louis. These varied in terms of size, social composition financial resources, and human capabilities. The remaining sixteen districts or individuals chosen were assumed interested in the project from an earlier communication and judged highly likely to offer feedback. No formal attempt was made to determine the demographic characteristics of these school districts, but they included a broad geographic representation.

Of the thirty persons receiving the evaluation packet, fifty-three percent returned the questionnaire within the next thirty days. Sixty percent (3 of 5) of the university or Project Review Committee responded, fifty-seven percent (8 of 14) of the local school districts, and forty-five percent (5 of 11) of those outside metropolitan St. Louis. The limited number of returns was disappointing, but understandable given the size of the reading assignment, the absence of any financial incentive, and the time of year, i.e., vacations and the beginning of school. A summary of the respondents' evaluation and comments regarding the August, 1975, draft of the manual version of the School Facility Planning System follows. Note that many of the specific suggestions were incorporated in the handbook's final editing during the Fall of 1975.

8.3.3 Limitations of the Evaluation

The instructions requested that each chapter be reviewed and evaluated separately. It was suggested that various staff members review the system components with which they were most familiar. The evaluation results were limited because of several factors:

By its very nature the format of the questionnaire has basic assumptions and limitations.

Several respondents did not return all seven of the evaluation forms. N=16 is accurate except where noted in the tables.

Respondents chose not to answer several items on the evaluation sheets. Therefore, these items were marked N/A and recorded by the evaluator.

The scale used and the small number of returns made uniting scores more meaningful but also broadened the interpretation.

The number of returns, although high in percentage, was very limited.

As a result of these factors, especially the small sample size, readers must exercise caution in interpreting the data. A more intensive and broader-based test must be conducted before conclusive judgements regarding the System are made.

8.3.4 Evaluation Results

The results of the questionnaire have been summarized by presenting the actual sheets that were distributed (Figures 8-1 to 8-7). The only difference is that instead of listing the continuum from one (completely disagree) to seven (completely agree) as presented in the questionnaire, the number of responses associated with each number on the continuum has been listed. Thus, if six individuals indicated that they completely agreed with the first statement by circling the number seven, a six has been recorded in that column. If no respondents circled number four (i.e., none were completely ambivalent) then a zero has been recorded in that column, etc.

In addition to the response tabulations, some of the comments have been included. These, of course, represent individual opinions. Most of the routine comments have not been printed.

Chapter One: Introduction. The introduction to the School Facility Planning System (SFPS) was generally understood and accepted by school administrators (See Figure 8-1). The terminology and organization of the material were apparently viewed as helpful. The use of graphs and charts to illuminate the interdependence among components was considered less successful.

Eighty percent (12) of the respondents agreed that the rationale for developing the School Facility Planning model was explained adequately. Two were uncertain, and one thought the rationale could be improved. There was general agreement that the SFPS's end-products were clearly stated but less concensus that the processes for conducting the analysis were adequately explained. One respondent was not certain whether the introduction to the planning process should be included in the chapter but felt, if such was the author's intent, that the interdependence of components needed clarification.

School administrators tended to agree that the advantages of the System were more adequately stated than its limitations. Interest in the possible implementation of the SFPS was varied, but few reasons were offered to support these views. One person, a member of the Project Review Committee, suggested that the information helped emphasize the need for a systematic approach, but that the introduction didn't do the total System justice. Seventy-three percent (11) of the respondents indicated that the material did sustain their interest.

It should be noted that the material on uncertainty (Section 1.4) was not in the chapter at the time of the evaluation. This section was moved forward, after substantial rewriting, from Chapter 7, at the suggestion of the National Science Foundation.

Chapter Two: Enrollment Component. Responses to the Enrollment Component indicated general understanding of and agreement with the explanations and the techniques (See Figure 8-2). Generally, the administrators agreed that the material was written and organized for implementation by school personnel. There was slight disagreement as to the value of the charts and graphs, with seventy-five percent agreeing that they understood. More than seventy-five percent of the respondents agreed that the techniques appeared reliable, that the examples were helpful, and that the caveats sufficient. Interest toward implementing the model waned in comparison with Chapter 1, possibly because of the volume of instructions, the time commitment necessary, and/or the availability of human resources. On average, it was estimated that the "work hours" required to complete the tasks assigned in the chapter would be beyond sixty hours.

Explanations of the various techniques in Chapter 1 were regarded, in general, as satisfactory. The cohort survival and ratio methods for enrollment projection were sufficient for eighty-one percent of the respondents. Explanations of the time trend projection, dwelling unit multiplier, and geographic distribution techniques for predicting enrollment were considered slightly less satisfactory There appeared to be a need to strengthen the explanation for projecting racial composition of future enrollment patterns.

Examination of the set of evaluating items for collecting historical data revealed slight differences in agreement. The cohort survival method and the geographic distribution of future enrollment were considered techniques where data could be assembled most readily. Curiously, the time trend projection, ratio method, dwelling unit multiplier, and enrollment by grade level techniques were believed to be methods where historical data would be more difficult to collect. Historical data for projecting the racial composition of future enrollment appeared to be the most difficult to gather. Fifty percent of the respondents were either undecided or left this item unmarked.

Estimating confidence intervals was reported as superficial by one respondent and appeared less than sufficient for fifty percent of the school personnel. Although historical data was not recognized as a problem, the response to this technque suggested the need for additional explanation or deletion.

Chapter Three: Facilities Component. Chapter 3 of the System was designed to help school administrators examine the impact of expected enrollment levels on future facility needs. From the evaluation questionnaire, it is evident that the information was understood, the terminology was consistent, and the sub-heading sequence helpful (See Figure 8-3). There was less agreement among the respondents as to whether the charts and forms were valuable and whether the chapter was written for implementation by school personnel.

Seventy-five percent of the sixteen persons returning the evaluation instrument agreed that they understood the general design of the Facility Component. Four respondents were uncertain as to whether a sufficiently clear description was offered. Several comments provided insights:

> Because of the size of this District and varieti[illegible] shapes, ages and types of schools, it would be extremely valuable to have [illegible] which gives a complete and realistic answer for each individual situation.
>
> Many considerations related to age of facilities and systems (heating, exterior, physical plant, grounds, etc.) were not covered. Trade-offs of long-range planning versus immediate [illegible] could be covered in more depth. There must be case studies you could draw [illegible] illustrate this struggle of long-range vs. immediate needs.
>
> We are a large district with 235+ schools, a large construction-rebuild program with currently declining enrollments and a future projected upswing; we need something like this.
>
> Candidly this chapter seems like a refugee from programmed learning! Like most of the other material in the series, many pages and hundreds of words are used to explain very simple concepts—consequently the concepts seem to get complex.

The concept of "level of effective enrollment" was reported as useful, though some believed that the definition and process for its calculation could be improved. Nine persons were in slight agreement that the concept was clearly defined with five others agreeing more strongly. Thirteen of the sixteen respondents agreed that the calculations and the usefulness of "level of effective enrollment" were adequate and valuable.

The methods suggested for yielding measures of future facility needs were questioned by a number of school administrators. The concept of "square footage" was considered substantially less reliable than the teaching station measure. The procedures described to execute the third component were apparently generally understood. Calculations appeared feasible for most districts and data calculations were helped by Forms A and B, though twenty-five percent of the respondents were uncertain in their understanding of the forms.

Difficulty in estimating the time necessary to complete the tasks in this component was expressed. Because of the numerous alternatives which must be considered, a precise time estimate was understandably hard to achieve. Forty hours or more was selected on the average.

Chapter Four: Fiscal Component. This component assists school administrators in examining the fiscal implications of alternative facility plans. It appeared more difficult than previous chapters to a number of respondents (See Figure 8-4). The number of responses which neither disagreed nor agreed with the evaluation statements was high—twenty-eight percent compared with a low of thirteen percent for Chapter 1. Many of the comments received were of a technical nature, suggesting that the component had been reviewed, by a number of school business officers.

> Most technically sound chapter of the manuscript. Written for the Finance Manager, not the Executive leader of the School District. Could easily be understood by the Superintendent if you would lead in with a case study of variables effecting itemization of factors to be considered. An appendix essentially outlining Chapter 4 could be

attached.

> Much too long. The population will fall into two groups. One, people who really understand and are already using something like this or two, people who won't understand this.

> Procedure outlined for Items 7, 8, and 9 appears to be tailored to a large school system. In my opinion the process is far too complicated and time-consuming for a small district. Projected costs, based on known costs per square foot, cost per student enrolled, and existing salary schedules adjusted to inflation, are better suited to the small districts.

> Overly complex presentation of relatively simple formula for projecting various fiscal components.

> Not enough discussion of the theory used to project costs. Need more discussion of advantages and disadvantages of various methodologies.

> Salaries and benefits can be projected more accurately by using on-hand staff as a base and computing increments, potential costs of living adjustments, etc.

> The treatment of supplies and materials and other expense projections is poor. Items totaling 10% to 25% of budget need greater emphasis.

> Utilities, for example, in recent years have been highly unstable in price. This is true also of many other commodities.

> The procedures for projecting future costs of construction, salaries, fringe benefits, etc., are clear, but to ascertain their validity is questionable.

> The instrument basically appears valid, but contains voluminous procedures that would probably need to be worked completely through before there could be total understanding.

Considering the evaluation comments and the clustering of responses toward the center of the continuum, interpretation of the data is difficult. This component was considered less understandable and appropriate for implementation than previous components. The chapter organization was considered more complicated than that of other chapters, while the sub-heading sequence and forms were reported as somewhat helpful.

Items 7 through 15 of the evaluation questionnaire had scores which ranged five to ten points lower than others on the instrument. The high number of "middle responses" on the [illegible] may have resulted from asking a double question, "clear and valid" on the items, or an honest uncertainty about the System's procedures.

Five of the sixteen respondents did not agree that the procedures for projecting future construction costs were clear and valid. Four persons disagreed that procedures for projecting linear growth or decline were clear and valid, while seven were uncertain of their answer. Procedures for projecting state and federal revenue were not sufficiently clear and valid to four respondents. The processes for projecting non-linear growth or decline and translating projected structures into assessed valuation were considered clear and valid by approximately eight of the respondents and unsatisfactory by three persons. Six and five persons respectively were undecided in their answers. The procedures for projecting supply and service operating costs were clear and valid to six respondents, eight were uncertain, and two disagreed. Nine persons agreed with the validity and clarity for projecting revenue from local sources, but again five were uncertain, and two disagreed.

While the majority of school administrators agreed that the directions for formulating a capital plan were clear, the usefulness of the overall analysis provided by the component was not certain. Nine persons indicated a middle of the continuum response, six agreed somewhat, and only one completely agreed to the usefulness of the overall analysis. Complementing the general findings of the evaluation was the fact that five of sixteen respondents appeared to lose interest in implementing the System, and four were uncertain. Over fifty percent of the school personnel appeared uninterested in completing the SFPS after reading the fourth component. They estimated fifty or more "work hours" to complete the tasks in this chapter.

In light of the greater concern expressed regarding this chapter, a substantial amount of editing was performed prior to the final typing and printing. Future evaluation will be necessary to determine the success of this revision actitivity. Perhaps the complexity and diversity of school financial operations prohibit the design of a generalized component acceptable to many districts.

Chapter Five: Geographic Component. This chapter, presenting a method for establishing attendance boundaries and facility sites, appeared to be less understood and less oriented to school administrators than previous chapters. Figure 8-8 illustrates the difference.

In general, the responses tended to agree with the statements on the questionnaire, but disagreements were more frequent than in previous chapters. (See Figure 8-5). Forms and terminology used in the component appeared questionable to several respondents. The data collection requirements and the techniques were also of concern. Only fifty percent of the persons agreed to the usefulness of the techniques. Little more than one-third of the respondents agreed that their interest was sustained toward implementing the total System.

Estimating the "work hours" to complete the tasks of the component at over fifty hours, the respondents offered a variety of interesting comments.

> The short introduction of Chapter 5. does not prepare one for the tedium of the explanation of the formulas. Unfortunately the early impression one has is that this procedure will require a mathematician to successfully reach one's final objective—successfully establishing feasible boundary lines or attendance areas. Overall the reader has the feeling that a somewhat straightforward procedure has been presented in difficult phraseology.
>
> For want of a better analogy—the reader cannot easily "see the forest for the trees."
>
> Superficial chapter. Needs much work. There are many alternatives to defining geographic boundaries than those you cite.
>
> Large district will make good use of this. The smaller ones won't understand it or won't try to.
>
> The text does not state for what size school districts this particular chapter should be used. The manual calculations are appropriate; using three (3) schools, with 5 enrollment grids accommodating 900 students, seems feasible for manual calculations, but to apply this to 12 schools and 30 enrollment grids would give a matrix of 372 squares which seems to me to be impractical for manual calculations. Have you made such calculations, estimating time involved?
>
> We are a large district. I found the formula somewhat confusing; perhaps the use of different letters for unknowns would improve this confusion.
>
> We have a computer-based combination pupil assignment, racial balance, bus routing, school opening time, etc., process, with a feature for options and projections.
>
> More attention needed to racial balance provisions if it is to have wide application.

In response to these comments, the final version of Chapter 5 has had the mathematical formulas deleted, and hopefully the general considerations and specific instructions clarified. It should now be clear that the Manual Version is not appropriate for very large school districts, or issues involving racial balance.

Chapter Six: Project Organization. The suggestions for preliminary planning prior to implementing a major facility planning study were understood by those responding to the evaluation questionnaire. Terminology and sub-heading sequence were judged appropriate and helpful. Using additional figures or charts was not seen as particularly necessary (See Figure 8-6).

Debate regarding the need for this kind of chapter and its proper location in the handbook first surfaced at the Project Review Committee meeting in April, 1975. The compromise reached was that because some readers might find the message useful a condensed discussion should be included. but in the back of the handbook, where it wouldn't "get in the way." The same issues were raised by the questionnaire respondents. One invividual viewed the chapter as geared to public relations; "to encourage the superintendent to involve the public in the planning process." Other comments indicated further differences in evaluating the chapter's worth.

> This chapter is too vague and generalized in parts. Needs a better outline and would suggest the technique of listing items for clarity within paragrpah organization. Regarding the suggestions for use of outside consultants, my personal opinion is that experienced, alert school administrators do a much better job of developing plans and analyzing needs than architects, planning engineers, or community planning consultants. There are some advantages, of course, in having citizens serving in an advisory capacity on some phases of planning.
>
> I am not convinced this belongs in the handbook at all, and if by chance it does, not as Chapter 6 and not as long. Maybe it could be merged into Chapter 1 and then as a chart or in outline form only.
>
> Very naive chapter. This strategy could work in building a school. It will rarely succeed in closing a school.
>
> Perhaps this chapter should precede other chapters?
>
> The chapter is more of an overview of considerations to be taken into account, without specific guidelines to assist the administrator in dealing with these considerations when planning the project organization structure.
>
> The chapter does not elaborate enough to provide one with a "handle" [illegible] procedures for organizational considerations
>
> Could be a good deal more useful if sample models were introduced and elaborated on.

Specific procedures suggested in the chapter were also questioned by school personnel. Although sixty-seven percent of the respondents agreed upon the validity of the "steps" for organizing a facility study, thirty-three percent or five persons were uncertain or disagreed. Most respondents agreed that the statements in the chapter were generally oriented to use by professional and lay groups, and that the needed human resources were realistic. But, again, a large minority, approximately twenty-six percent, were uncertain or disagreed. Similar ratios were found in regard to the usefulness of the component. Without considering the undecided persons, four individuals indicated their interest in implementing the total system was not sustained after reading the chapter; a slight majority suggested their interest was sustained.

Chapter Seven: Planning Considerations. Administrators found Chapter 7, which was written to help them review facility plan options and data, generally acceptable (See Figure 8-7). The terminology was indicated to be appropriate and consistent. School personnel believed the information was written for their implementation but were undecided as to whether charts and graphs would be valuable in providing additional meaning.

Information specific to the chapter was found agreeable by seventy-five percent (12) of the respondents. Several administrators were uncertain; but generally the "plan formulation" section, "data considerations" section, and "systems maintenance" section were thought to contain useful suggestions. Fifty-six percent (9) of the respondents sustained an interest toward implementing the SFPS, while thirty-one percent (5) and thirteen percent (2) respectively, were uncertain or lost interest.

Most comments were favorable, suggesting the chapter was well written and helpful. Some of the same concerns expressed about the level of sophistication and the physical location of Chapter 6 in the handbook were again apparent.

> Techniques for dealing with community issues should be treated much more fully. This is one of the better sections of the document! However, you still did not deal with the role of leadership in projecting some kind of vision for the schools; most people respond somewhat emotionally to school issues and all of the careful homework in the world can be for nothing if the emotional factors cannot be dealt with.
>
> Clarity of writing style is much better in data section than in others.
>
> Early sections appear quite simplistic. Perhaps this chapter should precede others?
>
> Adequate coverage of the major considerations. Of course, those who have lived through school closings can add to each section. Why not ask for anecdotal comments?
>
> I would have used most of this to amplify the introduction.

8.4 Conclusions

Examination of the questionnaire responses for all seven chapters of the User's Handbook: Manual Version revealed several patterns (See Figure 8-8). Most chapters were considered to be written in a consistent and understandable manner. Chapters 4, The Fiscal Component, and 5, The Geographic Component, appeared to need a clearer explanation of the procedures. Chapters 2 and 7 received higher scores on "implementation by school administrators" than did Chapters 5 and 6. Chapters 1 and 3 had moderate scores.

The use of charts, graphs, and forms was viewed as good in Chapters 2, 3, and 4, while, with the exception of a low score for Chapter 6, other components were average.

The percentage of "uncertain" scores, those respondents marking "4" in the middle of the 1-7 continuum, plus those items left blank on the questionnaire, might be considered enlightening. Chapters 4 and 5 had 28.4 percent and 27.4 percent of the possible responses marked "uncertain." Chapter 1 had thirteen percent where the other four components had approximately nineteen percent.

Chapters 4 and 5 also created the least interest toward implementing the System. Chapters 1, 2, and 7 sustained the most interest, while the other two components were average.

Based upon the project's specifications and the Project Review Committee's suggestions, it appears that a capital planning and budgeting capability, easily understood by local and non-technical professionals, was partially developed in the August 1975 draft.

The report editing conducted from September,1975, through December, 1975,attempted to incorporate many of the questionnaire suggestions. The organization of several chapters was revised, and a conscious attempt was made to eliminate redundancy and to clarify definitions.

Several major issues were not resolved. The overall size of the handbook was not materially reduced. A format was designed whereby the procedural steps were printed in bold on colored paper stock, thereby highlighting their separation from the more central explanatory material. Serious consideration of a separate brochure that would contain only the forms and a minimum of instructions was not possible within the remaining project budget. This approach was recommended by several reviewers. It should be examined in any follow-up testing and evaluation efforts. Similarly, the decision was made to keep the basic approach of placing introductory, and, for some, simplistic material (i.e., Chapters 6 and 7) at the end of the report.

The Computer Version of the School Facility Planning System benefited in some respects from the evaluation process in that Chapters 1, 6, and 7 have been placed in both handbooks. Chapters 6 and 7 become 7 and 8 respectively in the Computer Version. This handbook, however, has not received the critical review necessary prior to widespread dissemination. Both handbooks need further field testing before a conclusive evaluation can be made.

Note:

1. These teams consisted of Public Technology Incorporated, Washington, D.C., focusing on capital planning for fire stations and Curran Associates, Northampton, Massachusetts, focusing on capital planning for water and sewer facilities.

FIGURE 8–1 SUMMARY OF RESPONSES FROM SCHOOL ADMINISTRATORS*

CHAPTER 1 – SFPS Evaluation Response – Introduction

An introduction to the School Facility Planning System (SFPS) is offered in Chapter 1 for purposes of presenting school administrators with an overview of the System. Please indicate your reaction to this chapter on the remainder of this page, and the reverse side if necessary.

You are requested to circle a numeral along the continuum of 1 thru 7 to indicate the clarity and utility of the proposed system for public school districts. Both general and specific comments (referenced, where possible, to pages in the draft) will also be appreciated.

After completing this page, return the Chapter 1 materials to your evaluating coordinator or school superintendent.

Completely disagree — Completely agree

	1	2	3	4	5	6	7	N/A
1. The chapter was understandable.	0	1	0	0	3	5	6	0
2. The terminology was appropriate and consistent.	0	1	0	1	2	6	5	0
3. Sub-heading sequence assisted in understanding the materials.	0	1	0	2	1	3	8	0
4. The chapter was written for implementation by school administrators.	0	0	1	3	1	5	3	2
5. Charts and graphs were valuable in understanding the materials.	1	0	0	4	3	2	1	4
6. The rationale for developing the School Facility Planning System was explained.	0	0	1	2	3	5	4	0
7. The School Facility Planning System's end-products were clearly stated.	0	0	1	1	4	6	3	0
8. The process for completing the necessary analysis was adequately explained.	0	0	1	2	6	4	2	0
9. Advantages of the School Facility Planning System were adequately stated.	0	0	2	1	4	7	1	0
10. Limitations of the School Facility Planning System were adequately stated.	0	1	2	2	5	2	3	0
11. After reading the chapter, an interest in the possible implementation of the System was sustained.	0	0	2	1	2	4	5	1

*Numbers to the right of each item indicate quality of response as well as number responding (N = 15).

FIGURE 8—2 SUMMARY OF RESPONSES FROM SCHOOL ADMINISTRATORS*

CHAPTER 2 — SFPS Evaluation Response — Enrollment Component

Chapter 2, the Enrollment Component of the School Facility Planning System (SFPS) is designed to assist administrators in projecting school enrollments on a district-wide and sub-area basis. On these pages please respond according to your beliefs about the information in the chapter.

You are requested to circle a numeral along the continuum of 1 through 7 to indicate the clarity and utility of the proposed system for public school districts. Both general and specific comments (referenced, where possible, to pages in the draft) will also be appreciated.

After completing these pages, return the Chapter 2 materials to your evaluating coordinator or school superintendent.

	Completely disagree						Completely agree	
	1	2	3	4	5	6	7	N/A
1. The chapter was understandable.	0	0	0	1	8	5	2	0
2. The terminology was appropriate and consistent.	0	0	0	1	7	6	2	0
3. Sub-heading sequence assisted in understanding the materials.	0	0	1	1	4	6	4	0
4. The chapter was written for implementation by school administrators.	0	1	0	1	4	6	3	1
5. Charts and graphs were valuable in understanding the materials.	0	1	2	1	4	4	4	0
6. The reliability of the techniques appears sufficient to warrant use by public school districts.	1	0	0	2	5	5	2	0
7. The explanation of the cohort survival technique was sufficient.	0	0	1	1	2	8	4	0
8. Historical data could be assembled to use the cohort survival technique.	0	0	1	1	4	4	6	0
9. The explanation of the time trend projection technique was sufficient.	0	0	1	1	4	7	2	1
10. Historical data could be assembled to use the time trend projection technique.	0	0	1	2	4	4	4	1
11. The explanation of the ratio method technique was sufficient.	0	0	1	0	6	6	2	1
12 Historical and independent projection data could be assembled to use the ratio method.	0	0	0	4	3	3	5	1
13. The explanation of the dwelling unit multiplier technique was sufficient.	0	0	0	2	4	8	1	1

FIGURE 8–2 (continued)

CHAPTER 2 — [illegible]PS Evaluation Response — Enrollment Component

	Completely disagree 1	2	3	4	5	6	Completely agree 7	N/A
14. Historical data could be assembled use this technique.	0	0	0	4	5	3	3	1
15. The explanation of the technique for estimating confidence intervals was sufficient.	0	1	0	4	4	4	0	3
16. Historical data could be assembled to use this technique	0	0	0	1	6	6	0	3
17. The explanation of the technique for estimating enrollment by grade was sufficient.	0	0	1	1	3	7	2	2
18. Historical data could be assembled to use this technique.	0	0	2	1	2	7	2	2
19. The explanation of the techniques for projecting the geographic distribution of future enrollment was sufficient.	0	0	1	0	7	4	2	2
20. Historical data could be assembled to use this technique.	0	0	1	0	8	4	1	2
21. The explanation of the technique for projecting the racial composition of future enrollment was sufficient.	0	0	1	3	5	4	1	2
22. Historical data could be assembled to use this technique.	0	0	1	4	2	3	2	4
23. The examples provided in the text were helpful.	0	0	1	1	7	4	2	1
24. The caveats presented in the text were sufficient.	0	0	1	2	5	4	3	1
25. After reading the chapter, an interest in the possible implementation of the System was sustained.	0	0	2	1	4	3	2	3

26. Approximately how many "work hours" would be required to complete the tasks assigned in this chapter? 10–20–30–40–50–60+. (Response averaged 60 hours plus.)

*Numbers to the right of each item indicate quality of response as well as number responding (N = 16)

FIGURE 8-3 SUMMARY OF RESPONSES FROM SCHOOL ADMINISTRATORS*

CHAPTER 3 — SFPS Evaluation Response — Facility Component

Chapter 3 of the School Facility Planning System (SFPS) is designed to help school administrators examine the impact of expected enrollment levels on future facility needs. Please indicate your reaction to this chapter on the following pages, including the reverse side, if necessary.

You are requested to circle a numeral along the continuum of 1 through 7 to indicate the clarity and utility of the proposed system for public school districts. Both general and specific comments (referenced, where possible, to pages in the draft) will also be appreciated.

After completing these pages, return the Chapter 3 materials to your evaluating coordinator or school superintendent.

	Completely disagree						Completely agree	
	1	2	3	4	5	6	7	N/A
1. The chapter was understandable.	0	0	1	0	6	8	1	0
2. The terminology was appropriate and consistent.	0	0	1	2	5	5	3	0
3. Sub-heading sequence assisted in understanding the materials.	0	0	1	1	3	8	3	0
4. The chapter was written for implementation by school administrators.	0	0	2	2	3	6	2	1
5. Charts and graphs were valuable in understanding the materials.	0	0	1	4	0	6	5	0
6. Description of the general design was understood.	0	0	0	4	7	4	1	0
7. The "level of effective enrollment" was defined clearly.	0	0	1	1	9	5	0	0
8. Calculation of "level of effective enrollment" was described adequately.	0	0	2	1	7	5	1	0
9. "Level of effective enrollment" was a useful concept.	0	0	2	1	5	7	1	0
10. Square footage methods yield a reliable measure of future facility needs.	0	1	2	5	5	1	1	1
11. Teaching station methods yield a reliable measure of future facility needs.	0	0	1	3	7	3	2	0
12. The procedures for executing this component were understood.	0	0	1	2	4	8	1	0
13. The sequential development of the procedural steps was clear.	0	0	1	2	4	8	1	0

FIGURE 8--3 (continued)

CHAPTER 3 — SFPS Evaluation Response — Facility Component

	Completely disagree						Completely agree	
	1	2	3	4	5	6	7	N/A
14. Forms A and B were helpful guides when considering data collection.	0	0	2	1	2	7	4	0
15. Calculations using this component would be feasible for most districts.	0	0	0	2	3	9	2	0
16. Enough examples were presented to understand the techniques.	0	0	2	2	4	5	3	0
17. Form A was clearly understood.	0	0	1	4	2	7	2	0
18. Form B was clearly understood.	0	0	0	4	2	7	2	1
19. After reading the chapter, an interest in implementing the System was sustained.**	0	0	0	0	2	2	1	11

20. Approximately how many "work hours" would be required to complete the tasks assigned in this chapter? 4—8—12—16—20—30—40—50+. (Response averaged 40 hours plus.)

*Numbers to the right of each item indicate quality of response as well as number responding (N = 16)

**On the original form, the evaluation scale was inadvertently omitted, thus accounting for the low response.

FIGURE 8-4 SUMMARY OF RESPONSES FROM SCHOOL ADMINISTRATORS*

CHAPTER 4 – SFPS Evaluation Response – Fiscal Component

Chapter 4 of the School Facility Planning System (SFPS) is presented to help school administrators examine the fiscal implications of alternative facility plans. Please indicate your reaction to this chapter on the following pages including the reverse side, if necessary.

You are requested to circle a numeral along the continuum of 1 through 7 to indicate the clarity and utility of the proposed system for public school districts. Both general and specific comments (referenced, where possible, to pages in the draft) will also be appreciated.

After completing these pages, return the Chapter 4 materials to your evaluating coordinator or school superintendent.

	Completely disagree						Completely agree	
	1	2	3	4	5	6	7	N/A
1. The chapter was understandable.	0	0	1	4	6	5	0	0
2. The terminology was appropriate and consistent.	0	0	0	3	10	2	1	0
3. Sub-heading sequence assisted in understanding the materials.	0	0	0	3	6	5	2	0
4. The chapter was written for implementation by school administrators.	1	0	2	3	4	4	1	1
5. The figures and forms were valuable in understanding the materials.	0	0	2	3	6	2	3	0
6. The chapter organization was easily followed.	0	0	2	2	8	4	0	0
7. The procedures for projecting future construction costs are clear and valid.	0	0	5	3	6	1	1	0
8. The procedures for projecting salary and benefit operating costs are clear and valid.	0	0	3	5	6	1	1	0
9. The procedures for projecting supply and service operating costs are clear and valid.	0	1	1	8	4	1	1	0
10. The procedures for projecting linear growth or decline are clear and valid.	0	0	4	7	1	4	0	0
11. The procedures for projecting non-linear growth or decline are clear and valid.	0	0	3	6	3	4	0	0
12. The procedures for translating projected structures into assessed valuation are clear and valid.	0	0	3	5	3	4	1	0

FIGURE 8–4 (continued)

CHAPTER 4 — SFPS Evaluation Response — Fiscal Component

	Completely disagree						Completely agree	
	1	2	3	4	5	6	7	N/A
13. The procedures for projecting revenue from other local tax and non-tax sources are clear and valid.	0	0	2	5	4	4	1	0
14. The procedures for projecting revenue from state sources are clear and valid.	0	0	4	2	7	2	1	0
15. The procedures for projecting federal revenue are clear and valid.	0	0	4	3	4	4	1	0
16. The directions for formulating a capital plan are clear.	0	0	0	4	7	4	1	0
17. The overall analysis made possible with the Fiscal Component would probably be useful.	0	0	0	9	5	1	1	0
18. After reading the chapter, an interest in implementing the System was sustained.	0	0	5	4	4	0	1	2

19. Approximately how many "work hours" would be required to complete the tasks assigned in this chapter? 4–8–16–20–30–40–50+. (Response averaged 50+ hours.)

*Numbers to the right of each item indicate quality of response as well as number responding (N = 16)

FIGURE 8–5 SUMMARY OF RESPONSES FROM SCHOOL ADMINISTRATORS*

CHAPTER 5 – SFPS Evaluation Response – Geographical Component

Chapter 5 of the School Facility Planning System (SFPS) presents a method for establishing attendance boundaries and considering alternative sites for the closing or construction of a school. Please indicate your reaction to this chapter on the remainder of this page and the reverse side, if necessary.

You are requested to circle a numeral along the continuum of 1 through 7 indicate the clarity and utility of the proposed system for public school districts. Both general and specific comments (referenced, where possible, to pages in the draft) will also be appreciated.

After completing the page, return the Chapter 5 materials to your evaluating coordinator or school superintendent.

	Completely disagree						Completely agree	
	1	2	3	4	5	6	7	N/A
1. The chapter was understandable.	0	1	2	0	4	6	1	2
2. The terminology was appropriate and consistent.	0	0	2	1	6	4	1	2
3. Sub-heading sequence assisted in understanding the materials.	0	1	1	2	4	3	3	2
4. The chapter was written for implementation by school administrators.	0	2	2	2	3	2	3	2
5. Charts and graphs were valuable in understanding the materials.	1	1	1	3	1	4	2	3
6. The data collection requirements appear practical.	0	1	2	2	3	5	1	2
7. The technique would be useful in designating school attendance boundaries.	1	2	1	3	3	3	1	2
8. The technique would be useful in evaluating alternative sites.	2	0	2	2	4	3	1	2
9. After reading the chapter, an interest in implementing the System was sustained.	3	2	0	3	3	2	1	2

10. Approximately how many "work hours" would be required to complete the tasks assigned in this chapter? 4–8–12–16–20–30–40–50+. (Response averaged 50 hours plus.)

*Numbers to the right of each item indicate quality of response as well as number responding (N = 16)

FIGURE 8–6 SUMMARY OF RESPONSES FROM SCHOOL ADMINISTRATORS*

CHAPTER 6 — SFPS Evaluation Response — Project Organization

Chapter 6 of the School Facility Planning System (SFPS) offers suggestions for the preliminary planning that should precede any major facility planning study. Please indicate your reaction to this chapter on the remainder of this page and the reverse side, if necessary.

You are requested to circle a numeral along the continuum of 1 through 7 to indicate the clarity and utility of the proposed system for public school districts. Both general and specific comments (referenced, where possible, to pages in the draft) will also be appreciated.

After completing this page, return the Chapter 6 materials to your evaluating coordinator or school superintendent.

	Completely disagree							Completely agree
	1	2	3	4	5	6	7	N/A
1. The chapter was understandable.	0	0	0	0	4	6	4	1
2. The terminology was appropriate and consistent.	0	0	0	0	6	4	4	1
3. Sub-heading sequence assisted in understanding the materials.	0	0	0	0	5	5	4	1
4. The chapter was written for implementation by school administrators.	0	0	3	3	2	1	4	2
5. Additional figures would be valuable in understanding the materials.	2	1	1	3	2	2	2	2
6. The "steps" suggested for organizing a facility study appeared valid.	1	0	0	3	2	6	2	2
7. Statements generally were oriented to the use of professional and lay groups.	0	0	0	4	3	5	2	1
8. Human resources suggested to implement the School Facility Planning System were realistic.	1	0	0	2	3	4	4	1
9. The chapter constitutes a useful supplement to the System.	1	0	1	2	4	4	2	1
10. After reading the chapter, an interest in implementing the System was sustained.	2	0	2	1	3	4	1	2

*Numbers to the right of each item indicate quality of response as well as number responding (N = 15)

FIGURE 8—7 SUMMARY OF RESPONSES FROM SCHOOL ADMINISTRATORS*

CHAPTER 7 — SFPS Evaluation Response — Planning Considerations

Chapter 7 of the School Facility Planning System (SFPS) is designed to provide additional information to those administrators wishing to review facility plan options, additional relevant data and possibilities for updating the System in future years. Please indicate your reaction to this chapter on the remainder of this page and the reverse side, if necessary.

You are requested to circle a numeral along the continuum of 1 through 7 to indicate the clarity and utility of the proposed system for public school districts. Both general and specific comments (referenced, where possible, to pages in the draft) will also be appreciated.

After completing this page, return the Chapter 7 materials to your evaluating coordinator or school superintendent.

	Completely disagree						Completely agree	
	1	2	3	4	5	6	7	N/A
1. The chapter was understandable.	0	0	0	1	2	8	4	1
2. The terminology was appropriate and consistent.	0	0	0	2	1	8	4	1
3. Sub-heading sequence assisted in understanding the materials.	0	0	0	1	2	6	6	1
4. The chapter was written for implementation by school administrators.	0	0	2	0	4	3	6	1
5. Charts and graphs were valuable in understanding the materials.	1	1	0	5	1	3	4	1
6. The "Plan Formulation" section contained useful suggestions.	0	0	1	3	3	3	5	1
7. The "Data Consideration" section contained useful suggestions.	0	0	1	2	0	5	7	1
8. The "Systems Maintenance" section contained useful suggestions.	0	0	1	2	1	9	2	1
9. The chapter constituted a useful supplement to the System.	0	0	0	1	0	9	3	3
10. After reading the chapter, an interest in implementing the System was sustained.	0	0	2	2	2	4	3	3

*Numbers to the right of each item indicate quality of response as well as number responding (N = 16).

FIGURE 8—8 QUESTIONNAIRE SUMMARY
Agreement[a] — Uncertain Scores[b]

Statement	Ch. 1	Ch. 2	Ch. 3	Ch. 4	Ch. 5	Ch. 6	Ch. 7
1	13-0	15-1	14-0	10-4	8-2	14-1	14-2
2	12-1	15-1	12-2	13-3	9-3	14-1	13-3
3	11-2	13-1	13-1	13-3	8-4	14-1	14-2
4	8-5	12-2	9-3	6-4	4-4	4-5	11-1
5	5-4	9-1	10-4	9-3	4-6	2-5	6-6
6	11-2	12-2	12-4	10-2	6-4	9-4	10-4
7	12-1	13-1	13-1	3-3	3-5	10-5	11-3
8	11-2	13-1	11-1	5-5	4-4	10-3	11-3
9	10-1	12-2	11-1	4-8	1-5	8-3	12-4
10	7-2	11-3	4-6	1-7		4-3	7-5
11	9-2	13-1	11-3	4-6			
12		11-5	14-0	5-5			
13		13-3	12-2	6-5			
14		11-5	11-1	5-2			
15		7-7	14-2	3-3			
16		12-4	10-2	12-4			
17		11-3	10-4	7-9			
18		9-3	11-5	0-6			
19		12-2	5-11				
20		12-2					
21		9-5					
22		6-8					
23		12-2					
24		11-3					
25		8-4					

a Agreement = Scale numerals (5 + 6 + 7) — (1 + 2 + 3)
b Uncertain = Scale numerals (4 + N/A)

GLOSSARY

The following terms are used frequently throughout the School Facility Planning System documentation. In some cases the meaning may differ slightly from that commonly used by educational administrators.

Adequate Space — All existing facility space considered adequate for teaching purposes, and requiring no financial investment other than routine maintenance costs. In the Facility Component, adequate space is compared with required space to determine the expected space deficit or surplus.

Assessed Valuation — The real property tax base against which a tax rate is applied to yield local property tax revenue. Assessed valuation varies with the level and quality of urban development and local assessing policy. Techniques whereby it may be forecast are described in the Fiscal Component.

Asymptote — The upper (or lower) limit of a community. whether measured in terms of population, dwellings or assessed valuation. Some of the projection techniques used in the Enrollment and Fiscal Components allow the user to establish this upper (or lower) limit.

Attendance Area — A geographic area within a school district from which all public school children attend the same school. The Geographic Component is designed to help draw up attendance area boundaries.

Alternative School — A "non-school" approach oriented to students that are not interested in a traditional high school format (e.g., Philadelphia's Parkway Program or Chicago's Metro High School). This may be an important consideration in calculating "effective enrollment" in the Facility Component.

Bonding Capacity — The maximum bonded indebtedness permitted of a school district under state law. This may be calculated on a gross basis, usually as a percent of total assessed valuation. or on a net basis after existing outstanding indebtedness is considered.

Capacity — The number of students that can be accommodated in a school given its physical size and design, and the policies and standards endorsed by the school board.

Cohort Survival — A technique for projecting student enrollment by calculating the "survivors" from one grade to the next. Also known as the "Grade Succession" or "Grade Aging" technique.

Component — A major sub-system within the School Facility Planning System. The four analytical components are designed to be used independently or together, depending upon the needs of the user.

Confidence Interval — A range of values within which a projected variable such as enrollment or assessed valuation will fall a large percentage of the time. Also known as a confidence band, limit or envelop, this concept is very important in making long-range forecasts.

Course Enrollment — The average number of courses taken daily by individual students in a particular subject area multiplied times the number of students in the school or district. As described in the Facility Component, this variable is used to calculate "effective enrollment."

Demand — An expressed need or request for a commodity. A major objective of the School Facility Planning System is to help school districts forecast the future demand for public education and derive the facility implications.

Dwelling Unit Multiplier — A technique for projecting student enrollment based on a projection of residential dwellings and expected yield of school children per dwelling. Appropriate in rapidly growing districts.

Economy of Scale — A measure of the unit cost savings for land, labor, and materials that may be achieved by building a larger rather than smaller facility. The concept must be used carefully because the contribution to educational quality of any two school facilities will rarely be the same, and hence comparing their costs may be misleading.

Effective Enrollment — The number of students expected to be physically in attendance at a specific point in time during a typical school week. The desired teaching station or square foot standard applied against effective enrollment in the Facility Component yields a measure of required space.

Extended School Day/Year — A program for increasing the capacity of a school facility by reducing the number of children attending school at any specific time. The impact of staggered or double sessions, or a 12 month school year can all be "tested" using the Facility Component.

Facility — Any school space or building used to serve students. The user of the Facility Component may consider the need for any kind of space measured in terms of teaching spaces or square feet.

Found Space — Building space "discovered" within an existing school or "non-school" building (e.g., warehouse, industrial plant) for teaching purposes. An important consideration in formulating alternative facility plans.

Gompertz Curve — A special type of logistics curve in which the rate of change is decreasing exponentially. This function appears as an "S" curve, and has the form $P_{t+n} = \log K + (\log$ [illegible]$)(\log r^{n})$. It may be used in the computer-based version of the Enrollment and Fiscal Components.

Grade Organization — The manner in which a school system assigns its grades to elementary and secondary schools (e.g., 4-4-4, 6-2-4, 6-3-3, etc.).

Grid — The smallest geographic area for which dwellings and students are forecast in the System. Also known as "areas," grids may have irregular or rectangular boundaries. Data must be assembled by grid to support the Geographic Component.

Home-Base School — A school system in which the building is the "Home-Base" only for students' activities. High schools with work study programs or a "School Without Walls" are Home-Base schools with the potential for an enlarged student capacity.

Joint Occupancy — A method for sharing the cost of a facility between a public school district and some other organization (e.g., a city government) by sharing the space. An option to be considered in drawing up a fiscal plan and facility plan.

Linear Program — A mathematical technique which allows the value of a linear function to be minimized or maximized, subject to certain constraints. Linear programming is used in the Geographic Component to assign students to schools so that transportation costs are minimized.

Logistics Curve — An "S" shaped curve resulting from an exponential function of the form $P_{t+n} = K/1 + e^{a+bn}$ Techniques using this function are found in the Enrollment and Fiscal Components.

Module — A discrete set of tasks in the computer version of the System. Typically a component can be categorized in terms of several modules.

Open Campus — An increasingly popular concept that permits high school students to move freely inside and outside of school when not scheduled for a course. Adoption of an open campus policy will have implications for required teaching spaces, libraries, lounges, and other school space.

Periods Per Course — The average number of periods per course each student attends in a typical school week. This factor is used to help determine effective enrollment for a given subject area in the Facility Component.

Periods Per Day — The number of periods each day during which classes are held. As reviewed in the Facility Component, this factor will contribute to the calculation of effective enrollment.

Planning Period — The future time period over which forecasts will be made, and for which facility size and location decisions will be made. The planning horizon is the farthest year into the future for which facility planning will be conducted.

Policy — A course of action adopted by the school district which directly or indirectly impacts facility planning (e.g., staggered sessions, grade organizations, etc.).

Projection — A statement of conditions expected to exist in the future based on a set of explicit assumptions. The terms "projection" and "forecast" are used interchangeably throughout the documentation.

Ratio Method — A technique for projecting enrollment whereby students are estimated as a function of a projected ratio multiplied times an independently derived projection for a larger jurisdiction (e.g., county, state, or national).

Region — A geographical homogeneous sub-area of a school district for which independent projections are made. The typical district can be divided into two to four "regions" which in turn can be broken into as many as 30 "grids."

Regression Analysis — A statistical measurement of the form and strength of relationships between variables. Linear and exponential regression techniques may be used in the Enrollment and Fiscal Components for projection purposes.

Resource Center — A particular facility such as a library, art or vocational building which may attract students from more than one separate school. A consideration in developing a facility plan.

School District — A government entity engaged in the operation of public schools. The term is used synonymously with "school system," "local educational authority (LEA)," and "the user" throughout the documentation.

School Size — The desired maximum capacity or number of students per school type (e.g., elementary schools—400 children, high schools—1500 children, etc.). This standard may have an important bearing on a facility plan.

Square Feet — One of the measures of school capacity that may be used in the Facility Component. Gross or net square feet per student may be used. See Teaching Station.

Standard — A measure or criterion that directly or indirectly impacts facility planning (e.g., desired square feet per pupil, desired pupils per teaching station, etc.) as adopted by the school district.

Subject Area — Any course or combination of courses for which the effective enrollment is to be calculated in the Facility Component. In general, a particular subject area should be defined in light of similar space type requirements (e.g., regular classrooms, large classrooms, etc.).

Survey — The traditional approach whereby administrators inventory and evaluate school buildings, curriculum, and instructional techniques. The School Facility Planning System does not replace the need for comprehensive school surveys.

Teaching Station — Any classroom or learning space as defined by a school district, and used in measuring capacity in the Facility Component. See Square Feet.

Transportation Costs — A measure of the distance, time or money associated with transportation. The Geographic Component assists in the design of attendance boundaries, or the evaluation of school sites by indicating the configuration which will best reduce transporation costs.

Utilization Rate — The average percent of educational space which is occupied at any time during a typical school day. This factor is used to permit increased flexibility in determining space requirements in the Facility Component.

Uncertainty - A condition that characterizes all planning activity, especially where long-range forecasts or projections are involved. The School Facility Planning System has been designed to assist administrators in explicitly considering the reality of uncertainty.

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The following books, reports and articles constitute a small fraction of the literature relevant to educational facility planning. The material is organized in terms of six categories:

A. General School Planning
B. Capital Planning, Budgeting and Quantitative Methods
C. Enrollment Analysis
D. Facility Analysis
E. Fiscal Analysis
F. Geographic Analysis

With few exceptions the bibliography does not include general planning references, articles in "popular" educational journals, foreign literature or specific school plans. Educational Resource Information Center numbers (ERIC) and Dissertation numbers have been included where available.

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