ILLEGIBLE DOCUMENT

THE FOLLOWING DOCUMENT(S) IS OF POOR LEGIBILITY IN THE ORIGINAL

THIS IS THE BEST COPY AVAILABLE

AN INVESTIGATION INTO THE USE OF CONCEPTUAL LINEAR PROGRAMMING AND CAPITAL BUDGETING IN SCHOOL PLANNING

by

CLAUDE A. KEITHLEY

B. Architecture, Kansas State University, 1965

A MASTER'S REPORT

submitted in partial fulfillment of the

requirements for the degree

MASTER OF REGIONAL AND COMMUNITY PLANNING

Department of Community and Regional Planning
College of Architecture and Design

KANSAS STATE UNIVERSITY
Manhattan, Kansas

1973

Approved by:

Vernon P. Deines

ACKNOWLEDGMENTS

The sincere appreciation is gratefully acknowledged to all persons who contributed to the completion of this research effort, especially my father, Claude W. Keithley, who, in his wisdom, recognized the value of the education he could not, himself, receive.

TABLE OF CONTENTS

Page

LIST OF TABLES

LIST OF PLATES

LIST OF FIGURES

CHAPTER I

INTRODUCTION

In studies of planning and the behavior of people affected by planning, the investigator is often faced with evaluating many diffuse variables and factors which, when taken together, account for much of the observed variation in course of action, but which individually account for little.

The planner is necessarily concerned, not only with the "big picture," but with the inter- and intrarelationships of the smaller segments or land service units of the metropolitan area -- that is, districts, communities, and neighborhoods, the relationship of which is illustrated in figure 1.[1] It is, thus, the planner who must evaluate the elements within these land service units in order to arrive at a rational comprehensive development plan.

Such factors as commercial development, industrial development, residential development, open space and recreational development, and community facilities including civic and government centers, and school facilities must be included in an analysis of existing conditions and a projection of future needs. Within these categories, consideration must be given to such variables as:

(1) Household descriptive factors, including:

a. residential density, now and in the future,

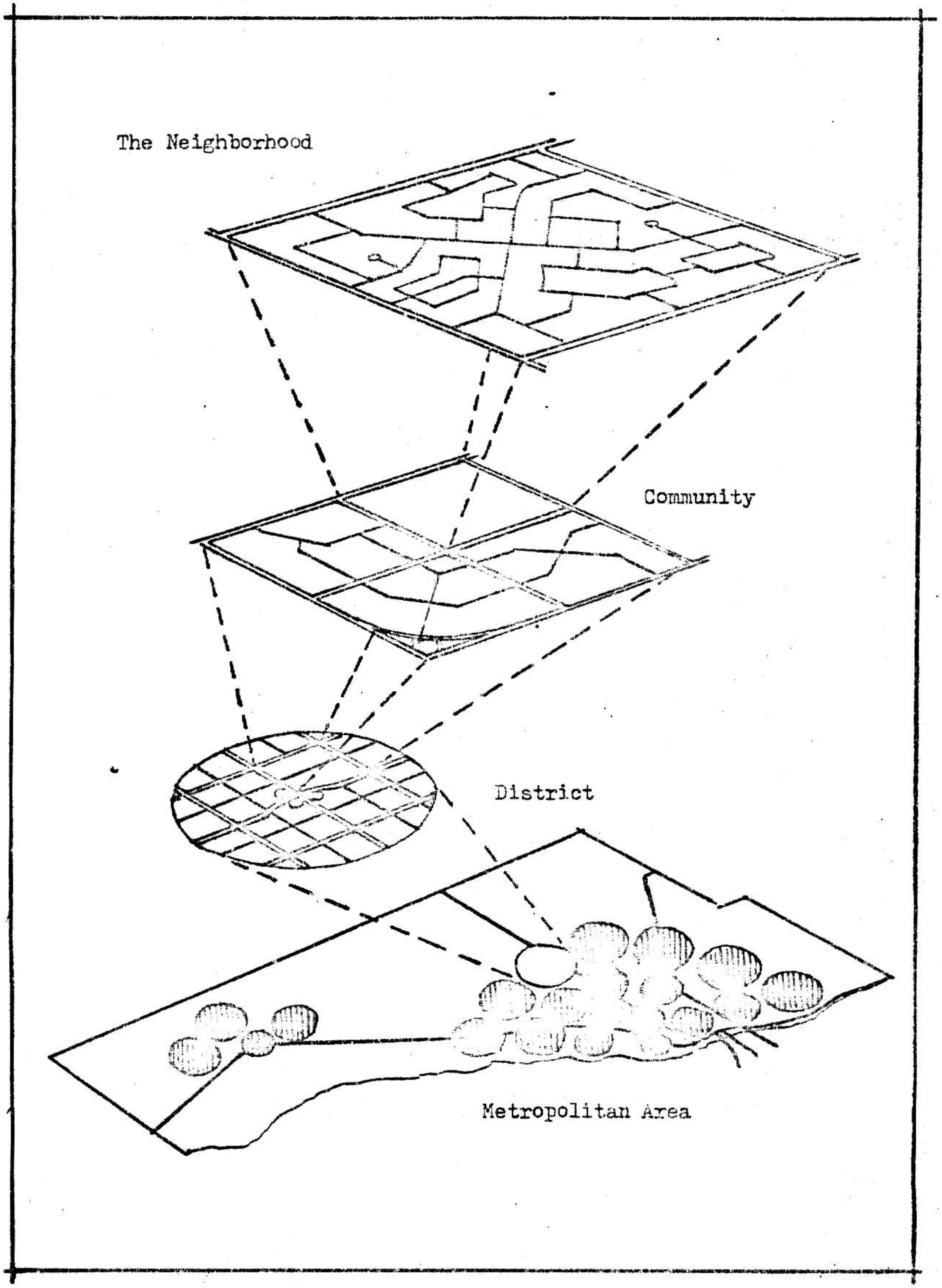
b. family size and composition,

c. secular characteristics, and

d. family income and occupations.

Figure 1

DELINEATION OF LAND SERVICE UNITS
METROPOLITAN DADE COUNTY



(2) Retail market factors, including:

a. size of market,

b. consumer and facility locations, and

c. accessibility.

(3) Transportation system factors, including:

a. distances and travel times to work, to school, to recreation, and to retail markets, and

b. congestion and levels of access by pedestrian, automobile, or public transit.

(4) Industrial factors, including:

a. plant location and facilities, and

b. utilities available.

(5) Financial factors, including:

a. land costs,

b. capital budgeting,

c. methods of finance,

d. tax rates and assessments,

e. maximum level of indebtedness allowed by law, and

f. construction costs.

All of these factors and more are a part of the planning process. The study of planned school construction reported in this paper represents only one of the subprocesses of the total, but one which presents many problems in the development of a comprehensive plan. Many of the factors listed above plus those listed below affect the actual construction of school facilities within a metropolitan area. Those other factors affecting the school directly include:

a. present and anticipated enrollments,

b. the adequacy of the existing school plants, and

c. the necessary expenditures for maintenance and construction, etc.

Yet, even if all of the significant variables could be identified and measured, the problem of determining their separate and joint effects upon school construction would remain. Taken together, these considerations imply the need for a greatly expanded storehouse of information, to say nothing of the additional effort needed to analyze and evaluate such data.

School Construction Problem

The planning process, as it is referred to today, must make some effort to evaluate the interrelatedness of the various data, not only for schools, but for commercial requirements, industrial requirements, and residential requirements, etc. Great strides have been initiated in this direction with the use of neighborhood analysis, cost-benefit analysis, gaming simulation, and programming models, but many of the valid methods of analysis have become so complicated in their manner and so diffuse in their terminology, that the average planner cannot comprehend enough information to render the models useful. But it remains his function to assemble a comprehensive guide for city growth based upon insufficient available information in the shortest amount of time possible. Therefore, methods need to be devised which will enable the planner to evaluate logically the factors affecting city growth. It is, thus, the intent of the author to hypothesize, and using linear programming techniques, investigate a model which may aid in evaluating one such factor: school construction within neighborhoods.

Basically, linear programming is a mathematical technique for dealing with complex problems involving the allocation of scarce resources among competing demands or uses. The solution that is derived either maximizes or minimizes a given linear expression representing the problem objective while at the same time it satisfies a set of linear conditional expressions or constraints. This technique has recently found application in a number of fields which are directly related to urban planning. It is the purpose of this report to explore the applicability of linear programming techniques to school planning while using financial constraints imposed by laws relating to capital budgeting and constraints dealing with the physical limitations feasible for various types of schools.

Chapter II represents a general review of the various models available for use by the planner and a selected glossary of relatively unfamiliar terms. The model for determining neighborhood school construction based on financial limitations is presented in Chapter III. Preliminary data pertinent to the application of the model to a selected study area is also included in Chapter III.

Chapter IV deals with the application of the model to the study are and the results obtained from a computer run using the primary data developed by Howard, Needles, Tammen, and Bergendoff, Consulting Engineers, Kansas City, Missouri, Urban Planning Department, and the secondary data developed in Chapter III that was needed for the model application to the study area.

Chapter V presents an analysis of the Utility of the model, problems inherent in its use, and potential extensions of the basic research for added utility to the planning profession. The derived model should be considered as a conceptual statement of potential relationships between school construction, maintenance costs, transportation costs and fiscal budgetary limits.

CHAPTER II

A LITERATURE REVIEW

The material presented in this chapter is intended to familiarize the reader with the various applications of models and programming techniques available to planners. While it would be impractical to provide a complete detailed description of the models, a brief mention of some of the more important is presented.

Relevant Terms

A model is a representation of a real world process in simplified form, unencumbered by irrelevancies.[2] In the usage here, it is a mathematical representation of a process previously conceptualized in verbal and logical form in theory. A model must seek to satisfy three requirements: first, that the model must grow out of a logically consistent organizing concept; second, that it have some relation to a process as it actually occurs or functions in reality; and third, that it have a dynamic quality which is capable of repetitive application and capable of taking into account feedback effects in the course of the stabilizing process.[3] The objective of much model-building is simulation. Literally, this word means imitation, and most simulations are imitations of real world processes either through a mechanical analog or through the operation of a computer process. Strictly speaking, the term simulation can be very broadly applied. Thus the formula $s = vt$ can be said to simulate uniform motion in such a way that the distances traveled can be determined.

A special sub-class of models of growing importance is oriented not to the external world which the planner hopes to control, but to the decision process of which he is a part. Some of these models simulate actual decisions processes, but most are abstract formulations of a problem of optimization - that is, finding the best solution to a problem. An important technique for solving certain optimization problems is called linear programming. This technique will find, by methods of successive approximations, an allocation which maximizes or minimizes a linear objective function. The allocation may be an allocation of construction to sub-areas, an allocation of families to dwelling units, or of budgets to projects. The objective function would be some measure of cost or benefit determined by multiplying each allocation by an associated coefficient and summing over all cases.[4]

The term "capital budget" has been used rather loosely. In fact, "there are so many kinds and varieties that a general definition is impossible."[5] A budget is, however, a reflection of decisions about the allocation of available resources. A budget is a plan and a budget projection is a plan for the future.[6] School Planning must rely on budget allocations and, therefore, must muster the community support necessary to assure that resources will be provided. School systems generally depend on three sources of state-local revenue support for public education: the property tax, state aid from general state revenue, and local nonproperty taxes.[7] School planning is but one element of the community which must be resolved within the planning process. The Capital Budget represents a real constraint imposed upon that process.

Some Illustrative Models. There are two general classes of models being tested and introduced into planning analyses. One class, called a growth index model, draws upon indices of various kinds, using them as forces regulating the development process. The gravity model has frequently been used, and sometimes a multiple regression equation is used to provide a composite index of a variety of factors significantly associated with growth or decline. The other class is based on a behavioral concept of development, with the model simulating the way in which households and firms reach location decisions.[8]

At this stage in model development, the Growth Index class of models have been used more generally than the other class. Walter G. Hansen, in 1959, used the concept of accessibility as an organizing concept for distributing to specific sections of the metropolitan area a given aggregate estimate of residential growth. His basic concept calls for the distribution of new population to zones according to their respective development potentials and holding capacities relative to those of all other zones in the metropolitan area.[9]

His model was found useful in small growing urban areas, but some kind of adaption became necessary when the approach was applied to large metropolitan areas where the central city was an area of declining population, with only the outlying suburbs receiving the growth.[10]

This problem led Lakshmanan and Fry to suggest a dual set of models, one for declining areas and one for growing areas.[11] Using a linear form of multiple regression, they developed general estimating equations for each of the two situations. In their study for the central city area such factors as age of district, the extent of nonwhite occupancy, and prestige were used as indices of change. Multiple regression techniques were also used to distribute service employment, construction-transportation-wholesale employment, and government employment using other appropriate indices.

For the local-serving retail sector, the gravity model has been widely used. More recently, Lakshmanan and Hansen have developed a "Retail Market Potential Model" which explores possible equilibrium distributions for large retail trade centers in the Baltimore metropolitan area.[12] Their study established that there exists a balanced distribution in which the size of centers is related to their drawing power, which in turn depends on the distribution of purchasing power projected for the area and the transportation facilities for trip-makers. The balanced distribution of retail outlets turns out to be the minimum cost pattern for trip-makers.

Other models of this class that are available to the planner are as follows:

(1) An Opportunity-Accessibility Model for Allocating Regional Growth[13]

(2) A Growth Allocation Model for the Boston Region[14]

The class of behavioral models are comprised of the simulation type which starts with a conceptual framework, and within this framework focuses on a particular organizing concept, and finally coming to the empirical problem involved.

The Pittsburgh model set forth by Lowry deals with the interactions of broad aggregates of activity.[15] The key feature of his model is the trip distribution indices computed from data assembled in the Pittsburgh Area Transportation Study. Using his model, Lowry obtained a distribution of retail and other forms of local-serving employment developing to serve his population.

Carrying Lowry's work further, Steger developed the Pittsburgh Urban Renewal Simulation Model for predicting the location of basic industry.[16] The prediction of residential locational choice on the basis of job location, and of the location of commercial activity on the basis of residential location, has been refined, making Lowry's model a more complete predictor of urban development.

As sketched out by Herbert and Stevens, the Penn-Jersey Transportation Study proposes a linear programming approach to distributing households in the metropolitan area.[17] The model is designed to find optimum locations for households of various income levels, recognizing four locational factors - a type of house, an amenity level, an accessibility combination, and a site size - with households locating to maximize their rent-paying ability and minimize their total land rent within certain constraints of the market.

Another model dealing with the simulation of residential development was developed by Chapin.[18] His model takes into consideration the competition for desirable sites, the consequent increases in the intensity of utilization, and the rents of these sites.

The San Francisco model represents yet another attempt to give attention to the decision making process which leads to changes of occupancy and the state of the housing stock in large cities.[19]

The Wisconsin model is part of a larger system-engineering approach being developed by the Southeastern Wisconsin Regional Planning Commission.[20] The overall approach involves the development and use of a regional economic simulation model and a land use simulation model, each with subsystems consisting of a linked set of submodels. The land use model is designed primarily as a tool for testing regional land use plans.

National and Regional Models. The simplest formulation of a spatial system grows out of the nonspatial input - output models originally developed by Leontief.[21] These models were intended to show the interdependence of economic activities in terms of flows of physical inputs and outputs. The underlying assumption of such models is that inter-industry flows can be identified and quantified and that there is a fixed relationship between input flows and output levels. A basic fault with this model is that it relates to a single region versus the "rest of the world," rather than to a trade within a system of comparable regions.[22] Basic data gathering is also a problem of major proportions. As a result, much of the potential usefulness of input - output analysis is untapped. However, the partial success which has been achieved thus far indicates that there will be greater future use made of this technique by planning analysts.

Walter Isard and Benjamin Stevens have postulated a regional economic model using linear programming which programs diverse production and shipping activities of any region to maximize the sum of regional incomes.[23] Transportation planning has utilized linear programming in a number of ways. One of these involves allocating funds for highway link improvements of a system, the objective being to minimize the user costs and the cost construction. Linear programming has been used to forecast residential location in a region by simulating the optimizing behavior of people as they seek to maximize their rent-paying ability (itself a function of household budget), housing costs, and the cost of interaction or transportation. A more appropriate use of linear programming is Schlager's land use plan design model. This model is designed to allocate various land uses to the different subareas of a region according to future demand and in accordance with stated design standards, at a minimum of land development costs.[24]

Summary - No attempt has been made here to probe in detail into the form and function of models presented. The advent of mathematical analysis has been received with mixed emotions. However, there is general recognition that such analysis can be of use in the solution of certain types of problems. The model presented in the succeeding chapter represents an attempt to overcome one such problem, thereby leaving the planner better able to concentrate on the other "human" factors in urban and regional development. Figure 2 represents the state of the art in modeling at this point in time.

Figure 2

CLASSIFICATION OF TWENTY URBAN PLANNING MODELS

Model Name	Author(s)	Approx. Date	Subject				Method		
			Land Use	Population	Transportation	Economic Activity	Econometric & Stochastic	Mathematical Programming	Simulation
How Accessibility Shapes Land Use	Hansen	1959	X	X				X	
Activities Allocation Model	Seidman	1964	X	X		X	X		X
Chicago Area Transportation Model	C.A.T.S. Group	1960	X		X	X			X
Connecticut Land Use Model	Voorhees	1966	X	X		X	X		X
Econometric Model of Metro. Employment and Pop. Growth	Niedercorn	1963		X	X	X	X		
EMPIRIC Land Use Model	Brand, Barber, Jacobs	1966		X		X	X		
Land Use Plan Design Model	Schlager	1965	X	X				X	X
Model of Metropolis	Lowry	1964	X	X		X		X	X
A Model for Predicting Traffic Patterns	Bevis	1959			X			X	
Opportunity-Accessibility Model for Alloc. Reg. Growth	Lathrop	1965	X	X	X				
Penn-Jersey Regional Growth Model	Herbert	1960	X					X	X
Pittsburgh Urban Renewal Simulation Model	Steger	1964	X	X		X	X		X
POLIMETRIC Land Use Forecasting Model	Hill	1965		X		X		X	X
Probabilistic Model for Residential Growth	Donnelly, Chapin, Weiss	1964	X				X		X
Projection of a Metropolis--New York City	Berman, Chinitz, Hoover	1960		X		X	X		
RAND Model	RAND Corp.	1962	X	X		X			X
Retail Market Potential Model	Lakshmanan, Hansen	1964			X	X		X	
San Francisco CRP Model	A.D. Little, Inc.	1965	X	X			X		X
Simulation Model for Residential Development	Graybeal	1966	X			X		X	X
Urban Detroit Area Model	Doxiadis	1967		X	X		X	X	

CHAPTER III

MODEL FORMULATION

Viewpoint

In discussing the educational system of a community, several viewpoints may be considered. The planners' viewpoint is such that a certain level of education should be provided for every child in the community, and that the school enrollments, or class size, has an effect on the instructors efforts to disseminate that certain level of education. Involved or associated with this viewpoint are certain costs of not providing this level of education, e. g. the cost of crime, the cost of lower income, the cost to retail sales, the cost of marketability appeal of the community to outside financial resources, the cost of not providing levels of community services and recreation. All of these factors must be evaluated with respect to what degree they would be acceptable within a community should the educational service level be lowered. The planner in search of an optimal pattern of growth must assume the desirable level of education be available to all school aged persons within his study area.

Assuming the educational level will be provided, the planner has the responsibility of evaluating the existing school plants to determine their adequacy now, and at the end of his planning period, both in structure and location in terms of anticipated growth. The problem of when a school of a certain type is to be built is solely dependent on when a neighborhood, community, or district can economically support that school with a minimum enrollment. Often locational criteria may dictate a new school where such anticipated enrollment is below that minimum accepted enrollment.

These occur where health, safety, and welfare of the student coupled with such physiographical factors as expressway location, railroads, drainage courses and streams, industrial district locations, etc. which isolate neighborhoods and present hazards to students in daily crossing are prevalent. In cases such as these, bussing may be considered as a logical alternative, however this becomes a decision of the school administrator and not a decision of the planner.

The school administrator views the problem of school location somewhat differently. Although he is concerned with the level of education offered to his community, and the social costs involved in not providing this level, he has a budget system within which he must organize his expenditures on all of the schools, existing and planned. He has before him such school system identifiable costs as operational and overhead expenses, including salaries, costs of building a new school plant, maintenance costs, cost of converting one school type to another, and transportation costs. The social cost of integration are also of real concern to the administrator, though unidentifiable in terms of his financial accounts.

All of these costs are variables dependent on numerous things. Maintenance costs are a function of the age and structural condition of the school plant. Transportation costs depend upon the number of busses required, a function of the number of students to be transported, distances involved, time, and maintenance costs. School plant construction costs and conversion costs are dependent on such items as: construction wages, materials, ever-rising land costs, consultants' fees for design, supervision, inspection and overhead, and, in general, the overall rise in the cost of living.

To further complicate his problem, the administrator is faced with the community's viewpoint of the education system, upon which the success or failure of school bond issues for new construction depends. Thus, it is the administrators responsibility to finance his educational system based upon his school budget, taxation revenue, endowments, and bond issues, providing for the community's desires concerning level of education acceptable (which the planner has adopted by either convincing the community of minimum desirable standards for development or adopting what is generally accepted by the community as desirable standards).

Basically then, the planner determines how many schools, by type, are required by the community to provide for a minimum acceptable educational level for every student within the study area throughout the planning period, the best location for a school within a neighborhood, community or district, the delineation of school attendance areas based on physiographical restrictions and acceptable maximum walking distances from each school type, a schedule of anticipated enrollments which indicate when a new school can be economically supported by a community, and a proposed school construction schedule based upon school size, location, and enrollment to satisfactorily provide for the assumed minimum acceptable educational level per student.

The school administrator, given the planner's solution, is responsible for the implementation of the educational plan by financing the system recommended by the planner within his budget framework and that provided by the other financial resources available to him. The decision can be considered to be made by the community upon acceptance of the planner's solution. At what point in time money must be added to the system to attain the goals of the plan is the decision of the administrator or school systems planner whose profession represents a combination of school system planning and school administration.

The planner has developed his solution without budget constraints because financial limitations were unrelated to the attainment of his goal of minimum acceptable educational level. The school systems planner can now add a budget constraint within which the system must be built. This may be broken down by allowable expenditure on school type within the planning period, and allowable expenditure on all schools constructed within a certain planning increment. At any rate, the objective is to determine the most economical school construction schedule, given the budget limitations and the planners solution of school needs within a study area. Stated another way, the objective function is to minimize new school construction costs, or that part of the total school system cost which would justify the issuance of new school construction bonds. All other school system identifiable costs can be assumed as part of the normal school operating budget, financed from other sources and thus, not a part of the new school construction problem. The operating budget, dependent on the number of schools, teachers, etc., becomes also dependent upon when a new school is added to the system of existing schools thereby increasing the number of teachers required, maintenance costs and educational equipment needed. Once an optimal construction schedule is obtained, a change can then be submitted to the operating budget to reflect the addition of schools to the existing system, thereby increasing the total financial resources needed to operate the entire system of schools. Included, however, in the school construction problem is a measure of the transportation costs and maintenance of plant costs to limit the choices of solutions and to offer an existing trade-off between building a school before a neighborhood can support that school with a minimum enrollment, thus increasing maintenance costs, and waiting to build a school, increasing the cost of pupil transportation.

Construction Costs

As many architects and educators readily admit, comparing the unit cost of one school with that of another is meaningless and often misleading. Costs simply indicate the number of dollars that are spent for a unit area, volume, or student. Unit costs are determined by dividing cost by another item, usually number of students, number of square feet, number of cubic feet, or number of classrooms. Since only the numerator or cost figure is definite, the unit cost loses much of its significance.

Unit costs can, however, be extremely valuable to the planner. Architects have used the cost per square foot as a predictor of the total cost of a building since the beginning of architectural cost analysis. It is not surprising, then, to find that a study,[25] conducted by Basil Castaldi, Bristol Community College, Fall River, Massachusetts, of two unit costs as a predictor of total cost indicated a coefficient of correlation between cost per square foot and total construction cost of 0.92, and a coefficient of correlation between cost per student and total construction cost of 0.71. Castaldi cited several inadequacies common to all unit cost figures. However, he readily admits that still the most reliable predictor of total construction cost is the unit cost per square foot. As such, cost figures to be used in the model will be of this variety.

The exact costs of construction of new schools in future years cannot be accurately ascertained. However, a reasonable approximation may be obtained with the use of Regression Analysis utilizing existing and past construction data as inputs. This method implies an assumption of linearity, and describes a straight line projection of past data. Research on the subject of construction costs has resulted in the data compilation of Table 1. These values were calculated from data obtained from interviews with Mr. H. L. Brotherson, Business Manager, Wyandotte County School District, Kansas City, Kansas, and Mr. G. Dewey Smith, Business Manager, Kansas City, Missouri Board of Education, and, though possibly in error when applied to a study area other than Kansas City, represent an approximation of school construction costs which will be utilized in the model.

Table 1

SCHOOL CONSTRUCTION COSTS
(1960)

School Type k	Cost per student	Average new School Construction Cost	Cost per Square Foot
Elementary school (k=1)	$1250	$0.4 Million	$12.50
Junior High school (k=2)	$2000	$1.5 Million	$15.00
Senior High school (k=3)	$1700	$2.2 Million	$14.80

The general trend in construction costs at the time of the study was three to four percent higher per year. As a result, the anticipated school construction costs (c_{ipk}) for each planning increment ($p = 1, 2, 3, \ldots.t$), using the maximum rate of increase, is that shown in Table 2 for a planning period of 20 years from 1970 to 1990 with four planning increments of five years each.

Table 2

ANTICIPATED SCHOOL CONSTRUCTION COSTS (c_{ipk})
(unit cost per square foot)

School Type k	Planning Increment (p) p = 1	p = 2	p = 3	p = 4
Elementary school (k=1)	$13.75	$15.80	$18.15	$20.75
Junior high school (k=2)	$19.60	$22.50	$25.90	$29.80
Senior high school (k=3)	$19.50	$22.40	$25.75	$29.60

Optimum, Minimum and Maximum School Size

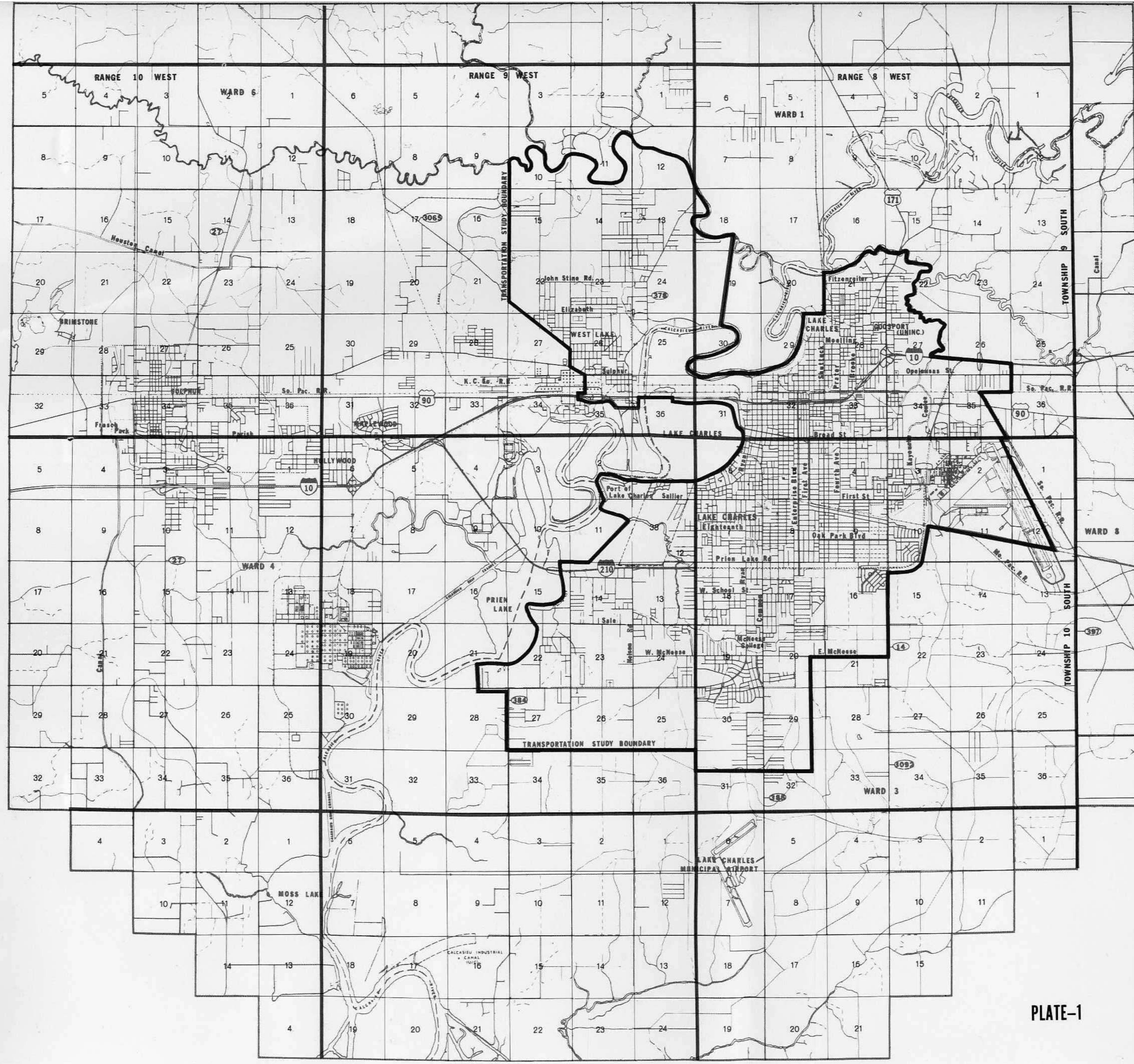
Obviously, schools vary in size throughout the country, region, city, and even neighborhoods due to such factors as neighborhood size, enrollments now and expected in the future, facilities included, etc. For planning purposes, however, an optimal size must be developed and applied to the neighborhoods of a study area. The Urban Land Institute, Washington, D.C., suggests the minimum, "ideal", and maximum enrollment standards included in Appendix A. Since the objective of the developing model is a minimum cost, there exists a minimum acceptable size school to provide space for either an "ideal" enrollment, or actual enrollment plus a factor of twenty-five percent [26] which is a reasonable design assumption for potential increase in capacity due to unforeseeable growth.

The school discussed in this report is based upon the self-contained classroom concept, which is currently popular throughout the United States. Appendices B and C includes specific information about spaces commonly found in conventional elementary schools and secondary schools, e.g. types, number, and size of spaces,[27] and, the minimum acceptable school size required for the "ideal" enrollment.

Table 3

SCHOOL SIZES

School Type	Absolute Minimum		Optimum		Maximum		Model Limit (Greater Than Absol. Min.)
	Enrollment (Student)	Area (Sq. Ft.)	Enrollment (Student)	Area (Sq. Ft.)	Enrollment (Student)	Area (Sq. Ft.)	
k = 1	230	25,000	700	50,000	900	62,500	12,600 sq. ft. + 55 sq. ft. per student
k = 2	750	90,000	1,000	100,000	1,500	120,000	60,000 sq. ft. + 40 sq. ft. per student
k = 3	900	125,000	1,500	150,000	2,500	170,000	90,000 sq. ft. + 40 sq. ft. per student



LEGEND

TRANSPORTATION STUDY AREA BOUNDARY	
TOWNSHIP BOUNDARY	
SECTION BOUNDARY	
SECTION NUMBER	16

Plate I

LAKE CHARLES METROPOLITAN PLAN AND TRANSPORTATION STUDY

STUDY AREA

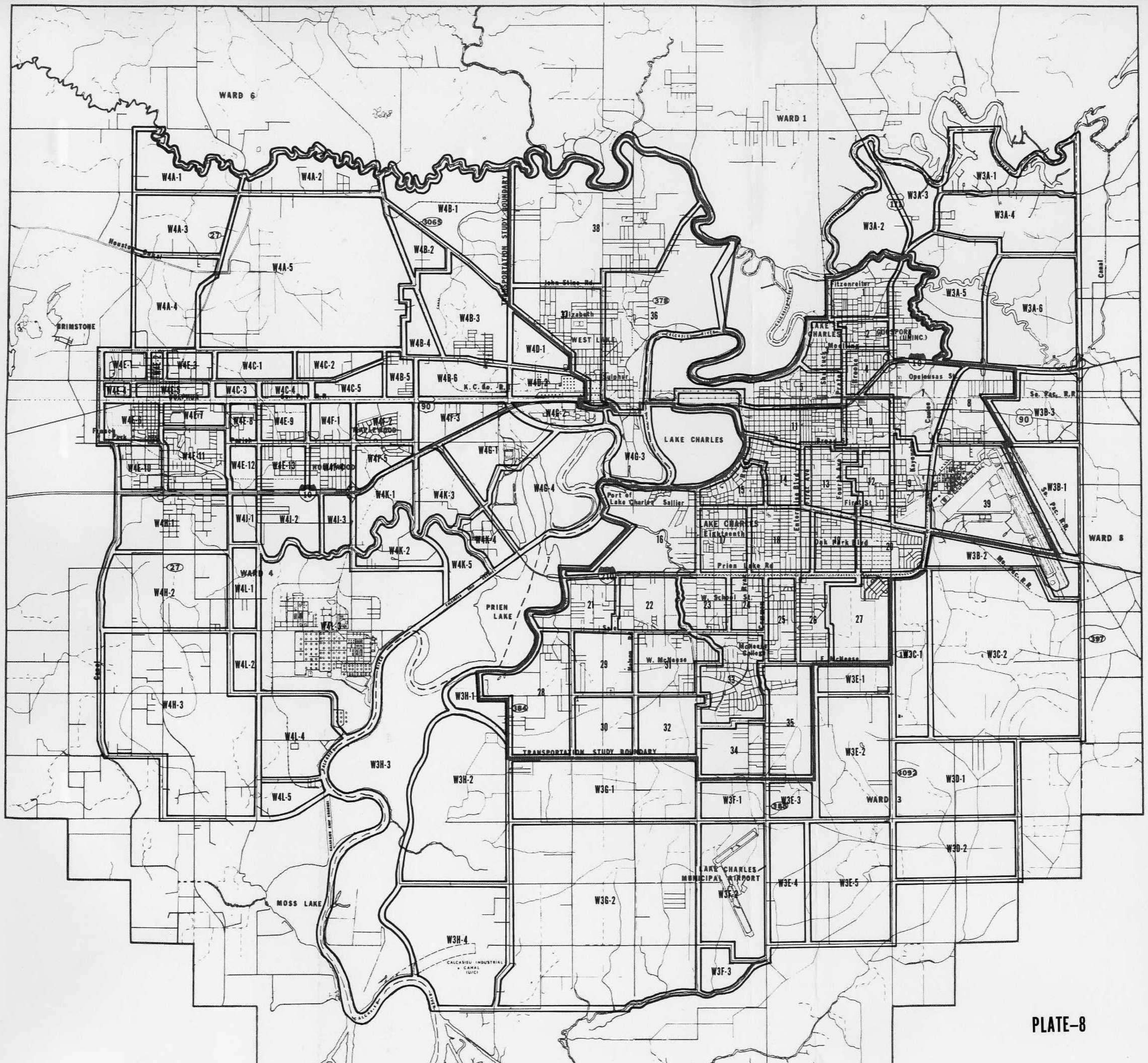
1 Inch = 2 Miles

STATE PROJECT NO. 736-00-81

FEDERAL AID PROJECT NO. HPR-1(3)

HOWARD, NEEDLES, TAMMEN & BERGENDOFF

KANSAS CITY NEW YORK



LEGEND

PLANNING ANALYSIS UNITS INSIDE TRANSPORTATION STUDY AREA	24
PLANNING ANALYSIS UNITS OUTSIDE TRANSPORTATION STUDY AREA	W4A-4
PLANNING ANALYSIS UNITS BOUNDARY LINE	—

Plate II

LAKE CHARLES METROPOLITAN PLAN AND TRANSPORTATION STUDY

PLANNING ANALYSIS AREAS

1 Inch = 2 Miles

STATE PROJECT NO. 736-00-81
FEDERAL AID PROJECT NO. HPR-1(3)

HOWARD, NEEDLES, TAMMEN & BERGENDOFF
KANSAS CITY NEW YORK

The minimum school size can be considered as having basically two parts -- the space devoted to the administrative unit (considered as a constant for purposes of the model, although in reality, a function of the number of teachers required at the school plant) and the classroom area (a function of the number of students it is to serve). As such, the minimum school size for each school type k can be determined with the relationships expressed in Appendices B and C. Applying the ULI Standards (Appendix A) on minimum acceptable school enrollments to the above relationships indicate the absolute minimum school size, optimum, and maximum school size to be that given in Table 3. The "limits" column indicates the general relationship between the two functional units of the school and, except where less than the absolute minimum size school, will be used to evaluate the minimum space constraints imposed on the model.

Determination of Minimum Space Constraints for Case Study

Obviously, the minimum space required for a school system is dependent upon the study area and its needs in order to provide a minimum level of education. The study area selected to initially test the model is that containing Lake Charles, Louisiana, a comprehensive development plan for which was underway by Howard, Needles, Tammen and Bergendoff, Urban Planning Department, Kansas City, Missouri, in 1966. The study has since been completed and the results within the education sector can be compared with that developed by the model. The Study Area and Planning Analysis Areas, or neighborhoods, are shown in Plates I and II respectively.

Neighborhood Analysis was performed on the Study Area and the results relevant to the application are listed below. Since one assumption of the model is that the results of the neighborhood analysis are correct, a discussion of how the results were obtained is not considered relevant.

1. The number of planning increments within the planning period are four ($t = 4$).

2. The number of school types k required in the Study Area are three ($s = 3$): Elementary school ($k = 1$); Junior high school ($k = 2$); Senior high school ($k = 3$).

3. The number of school types k required at the end of the planning period (n_k) are as follows for the various k's:

$$n_k = 15 \text{ for } k = 1$$
$$n_k = 4 \text{ for } k = 2$$
$$n_k = 5 \text{ for } k = 3$$

4. The number of neighborhoods (N) within the Study Area is 38, ($N = 38$).

With the given information obtained from neighborhood analysis of the Study Area, and the minimum acceptable school size, the minimum space constraint can be determined, as in Table 4 for the Study Area. This table gives the minimum space/area to be constructed within the planning period for each type of school, and the total minimum acceptable space. The value of these construction constraints was found by comparing the minimum school size determination and the absolute minimum school size. The larger value is used as the minimum. The difference between column (7) and column (6) is attributable to aggregating enrollments to determine the minimum space requirements, thereby causing individual schools having less than the minimum acceptable enrollment to support a school to be overlooked in determining total space requirements.

Table 4

CONSTRUCTION CONSTRAINT DETERMINATION PER SCHOOL TYPE
LAKE CHARLES, LOUISIANA STUDY AREA

School Type (1)	Number of Schools Needed (2)	Anticipated Enrollment (Students) (3)	Area Required Per Student (Sq. Ft.) (4)	Area Required Admin. Unit. (Sq. Ft.) (5)	Minimum Area Required (Sq. Ft.) (3)(4) + (2)(5) (6)	Absolute Minimum Area Required* (Sq. Ft.) (7)	Adjusted Anticipated Enrollment (Students) (3) x 1.25 (8)	Maximum Area Justified (Sq. Ft.) (2)(5) + (8)(4)
k = 1	15	7,131	55	12,600	581,205	581,505	8,914	679,270
k = 2	4	3,151	40	60,000	366,040	381,160	3,939	397,560
k = 3	5	5,910	40	90,000	648,779	669,159	7,387	745,480

Total Construction Constraint $\left(\sum_{i=1}^{N} \sum_{p=1}^{t} \sum_{k=1}^{s} X_{ipk}\right)$ 1,631,824

Total Maximum Space Justified 1,822,310

*Determined by finding minimum school size for each neighborhood separately, comparing with absolute minimum space to be constructed per school type and using whichever was larger, and summing over all neighborhoods. Column (2) would equal column (6) if all schools required, have enrollments greater than the minimum required enrollment to economically support the school.

Maintenance Costs

Maintenance of Plant consists of those activities that are concerned with keeping the grounds, buildings, and equipment at their original condition of completeness or efficiency, either through repairs or by replacements of property (anything less than replacement of a total building). Included in this account are salaries of carpenters, painters, plumbers, electricians, groundskeepers, and similar personnel engaged in the maintenance of plant, expenditures for the upkeep of grounds, repair of buildings, and equipment by personnel who are not on the payroll of the school district, and expenditures for piece-by-piece replacements of instructional and noninstructional equipment.

Since the problem of new school construction is concerned primarily with the new school plant, the maintenance costs can be considered a function of salaries, contracted services, and replacement of equipment. Salaries, for the most part, can be considered as increasing as the general cost of living increases, and can be expected to be funded from the general school budget. Contracted services and equipment replacement are variables dependent on time increasing as the new plant becomes older and, as such, a portion of the school construction problem. Further research in this area may prove useful in order to approach a realistic assessment of actual maintenance costs of new school plants. However, for purposes of this paper, maintenance costs will be assumed as shown in Table 5 for schools constructed in the respective planning increments. The pattern represents a curvilinear relationship between maintenance cost and time, increasing at a greater rate as time increases. The cost is expressed as a percentage of total square feet built per planning increment as a basis for inclusion in the model as a penalty for constructing a school before a neighborhood can support that school with a minimum enrollment, and to better assess the problem of school construction within budgetary limits.

Table 5

ANTICIPATED SCHOOL MAINTENANCE COSTS
(Expressed as Percent of Square
Foot Built For a 5 Year
Planning Increment)

	p = 1	p = 2	p = 3	p = 4
All School Types Constructed in Increment 1	0.0	0.04	0.08	0.13
All School Types Constructed in Increment 2		0.0	0.05	0.10
All School Types Constructed in Increment 3			0.0	0.06
All School Types Constructed in Increment 4				0.0

Transportation Costs

Under the neighborhood school concept, it is hypothesized that the students residing in a neighborhood that is presently lacking a school of k type will be transported by means requiring public funds to a nearby neighborhood having a school of k type, and further, that this cost will be reflected in the school budget. As a result the cost of not building a school in a specific planning period can be added to the model as an underlying trade-off.

Selected statistics on student transportation in the United States for selected years is presented in Table 6:

Table 6

STATISTICS ON STUDENT TRANSPORTATION
FOR SELECTED YEARS 1926 - 1962

Year	Students Transported at Public Expense	Public Funds Expended for Transportation	Average Cost Per Student
1941 - 1942	4,503,081	$ 92,921,805	$20.63
1945 - 1946	5,056,966	129,756,375	25.66
1949 - 1950	6,980,689	204,611,283	29.30
1953 - 1954	8,906,126	308,704,303	34.67
1957 - 1958	11,343,132	419,539,863	36.99
1961 - 1962	13,687,547	540,168,114	39.46

Using 1940 as the base year for measuring time and applying "least squares" Regression Analysis to the average cost per student column indicates the linear trend in the cost of transporting students. The general equation for the line best representing this trend is that expressed by equation (0.0).

(0.0) $$T_{ipk} = 0.95\, X_T + 20.67$$

where: T_{ipk} = average transportation cost per student within the United States.

X_T = difference in years between when the students are to be transported and the base year (1940).

Transportation costs within states or regions of the United States may vary significantly as E. Glenn Featherston and D. P. Culp report in their book, "Pupil Transportation".[28] For instance, the number of students transported in Louisiana for 1961 - 1962 was 408,097 at a cost of $19,082,710.[29] The average cost per student can be calculated to be $46.76 or $7.30 greater than the national average for that year. As such, applying the same national trend to a particular region or study area may be grossly misleading. However, for purposes of model application, the same rate of change as was exhibited in the United States as a whole will be assumed applicable to the study area of Lake Charles, Louisiana. The equation for approximating anticipated transportation costs for the study area then becomes equation (0.1):

$$(0.1) \qquad T_{ipk} = 0.95\, X_T + 27.97$$

The anticipated transportation costs for the study area and respective planning increments are shown in Table 7. The cost in terms of square feet per student was determined by dividing the anticipated transportation costs per student by the anticipated construction costs per square foot shown in Table 2 for each school type.

Table 7

ANTICIPATED TRANSPORTATION COSTS (T_{ipk})
LAKE CHARLES, LOUISIANA

	p = 1	p = 2	p = 3	p = 4
average cost/student/yr.	$ 56.47	$ 61.42	$ 65.97	$ 70.72
cost/student/planning increment	282.35	307.10	329.85	353.60
cost/student/sq. ft./ planning increment				
k = 1	20.5	19.5	18.0	17.0
k = 2	14.5	13.5	12.5	12.0
k = 3	14.5	13.5	13.0	12.0

It is obvious that the cost of not constructing a school will have a real effect on the total budget limitations of school construction when added to the total cost of construction as a non-construction cost.

Budget Parameters

The planning solution derived from neighborhood analysis has indicated that n schools of k type are desirable within a given planning period for a particular study area. Since construction costs of schools are increasing every year, a schedule of costs may be developed for any point in time within the planning period based upon an assumption of the percentage increase in cost applicable for the study area, and the assumed relationship between cost and time, e.g. linear or curvilinear. Since costs of labor and materials may vary from region to region, an analysis of these total costs would be useful in reducing error in these cost assumptions.

At any rate, the school systems planner must determine a sound financing plan for the new school system. He may assume that the schools will be constructed as the planner suggested, based on anticipated enrollments, which would necessitate the addition of financial resources without concern for the end total system costs, or try to minimize the total end costs, still providing for the minimum accepted level of education.

By adopting the latter approach an average working budget may be developed. An approximation may be derived by multiplying the number of n schools of k type required, by the average construction cost of school type k and summing over all school types. This relationship is expressed mathematically by equation (1.0):

$$(1.0) \qquad B_{ta} = \sum_{k=1}^{s} \left(\frac{n_k}{t} \sum_{p=1}^{t} C_{ipk} \right)$$

where:

B_{ta} = total average budget

n_k = number of schools of type k required, as determined by the planners neighborhood analysis

c_{ipk} = new school construction cost during each planning increment p for school type k in neighborhood i

t = number of planning increments in the total planning period

s = number of school types k, e.g. elementary school, junior high school, senior high school, junior college, etc.

The total average expenditure on school type k is then expressed by equation (1.1):

$$(1.1) \qquad B_k = \frac{n_k}{t} \sum_{p=1}^{t} c_{ipk}$$

The following budget parameter is a function of the assumed expenditure pattern for the school system. Since construction costs continually increase with respect to time, and the objective function is to minimize the total cost of the system while providing a specified level of education, it is a safe assumption that greater capital outlays should occur at the beginning of the planning period as opposed to the end of the planning period in order to make optimal use of the capital anticipated from the bond issue.

The expenditure pattern adopted for a given study area should reflect the over-all awareness of the number of total new schools needed, the Capital Budget and assessed valuation of the study are and the construction capability of the contractors and builders who will be implementing the school system plan. The expenditure pattern selected for Lake Charles is that indicated below for the four planning increments in the planning period. It is expressed as a percent of the total average budget.

(1.2)
$$b_p = 0.58\ B_{ta} \text{ for } p = 1$$

$$b_p = 0.20\ B_{ta} \text{ for } p = 2$$

$$b_p = 0.12\ B_{ta} \text{ for } p = 3$$

$$b_p = 0.10\ B_{ta} \text{ for } p = 4$$

where:

b_p = total allowable expenditure during planning increment $p = 1, 2, 3, \ldots, t$

The construction constraint per planning period can be derived from the total allowable expenditure per planning increment and the average construction cost during that increment. This relationship is expressed in equation (1.3):

(1.3)
$$\sum_{i=1}^{N} \sum_{k=1}^{s} X_{ipk} = \frac{Sb_p}{\sum_{k=1}^{s} c_{ipk}}$$

where:

$\sum_{i=1}^{N} \sum_{k=1}^{s} X_{ipk}$ = square feet of space to be constructed in neighborhood $i = 1, 2, 3, \ldots, N$ in planning increment $p = 1, 2, 3, \ldots, t$ for school type $k = 1, 2, 3, \ldots, s$

N = total number of neighborhoods within the study area

Applying equations (1.0), (1.1), (1.2), and (1.3) to the Lake Charles Study Area indicate the construction constraints per planning increment to be that shown in Table 8.

Table 8

BASIC CONSTRUCTION CONSTRAINT DETERMINATION PER PLANNING INCREMENT
LAKE CHARLES, LOUISIANA STUDY AREA

School Type (1)	n_k Number of Schools Needed (2)	Maximum Area Justifiable (Table 3) (3)	Assumed Construction Distribution (0.58) p = 1	(0.20) p = 2	(0.12) p = 3	(0.10) p = 4
k = 1	15	679,270	393,977	135,854	81,512	67,927
k = 2	4	397,560	230,585	79,512	47,707	39,756
k = 3	5	745,480	432,378	149,096	89,458	74,548
(A) Tot. expendable budget B_{TA}		$35,462,716	$18,368,021	$7,275,263	$5,018,597	$4,800,835
(B) Tot. construction per increment			1,056,940	364,462	218,677	182,231
(C) Ave. cost per increment (construction only)/sq. ft.			$17.38	$19.96	$22.95	$26.34
(D) Calculated expenditure distribution			0.52 B_{TA}	0.21 B_{TA}	0.14 B_{TA}	0.13 B_{TA}

Tables 8.1, 8.2 and 8.3 represent an adjustment to construction constraints determined in Table 8 as a result of needed increases due to estimated maintenance cost and pupil transportation costs. The adjusted construction constraint values are those which will be utilized as constraints to the model.

Table 8.1

ADJUSTED CONSTRUCTION CONSTRAINT DETERMINATION
PER PLANNING INCREMENT
ELEMENTARY SCHOOLS (k=1)
LAKE CHARLES, LOUISIANA STUDY AREA

	p = 1	p = 2	p = 3	p = 4
Basic Constraint (Table 8)	393,977	135,854	81,512	67,927
Increase based on Maintenance Costs of Schools Constructed in p = 1	3,940	15,759	31,518	51,217
p = 2	----	2,038	6,793	13,585
p = 3	----	----	1,630	4,891
p = 4	----	----	----	1,698
Increase based on Transportation Costs	37,823	22,517	11,016	0
Adjusted Construction Constraint	435,740	176,168	132,469	139,318

Table 8.2

ADJUSTED CONSTRUCTION CONSTRAINT DETERMINATION
PER PLANNING INCREMENT
JUNIOR HIGH SCHOOLS (k=2)
LAKE CHARLES, LOUISIANA STUDY AREA

	p = 1	p = 2	p = 3	p = 4
Basic Constraint (Table 8)	230,585	79,512	47,707	39,756
Increase Based on Maintenance Costs of Schools Constructed in p = 1	2,306	9,223	18,446	29,976
p = 2	——	1,193	3,976	7,951
p = 3	——	——	954	2,862
p = 4	——	——	——	994
Increase Based on Transportation Costs	13,745	7,369	3,475	0
Adjusted Construction Constraint	246,636	97,297	74,558	81,539

Table 8.3

ADJUSTED CONSTRUCTION CONSTRAINT DETERMINATION
PER PLANNING INCREMENT
SENIOR HIGH SCHOOLS (k=3)
LAKE CHARLES, LOUISIANA STUDY AREA

	p = 1	p = 2	p = 3	p = 4
Basic Constraint (Table 8)	432,378	149,096	89,458	74,548
Increase Based on Maintenance Costs of Schools Constructed in p = 1	4,324	17,295	34,590	56,209
p = 2	—	2,236	7,455	14,910
p = 3	—	—	1,789	5,367
p = 4	—	—	—	186
Increase Based on Transportation Costs	21,766	12,513	6,500	—
Adjusted Construction Constraint	458,468	181,140	139,792	151,220

The Basic Model

The objective function of the model, as stated previously, is to minimize cost: Z, where Z equals the total cost of the new school system construction supported by the issuance of school bonds, stated in linear programming format, the model becomes that expressed by equation (2.0):

$$(2.0)\quad \text{Minimum: } Z = \sum_{i=1}^{N} \sum_{p=1}^{t} \sum_{k=1}^{s} \left[(C_{ipk} + M_{ipk})X_{ipk} + T_{ipk}Y_{ipk} \right]$$

where Z = total cost of new school system recommended by the school systems planner.

X_{ipk} = square feet of school space to be constructed for school type k (k = 1, 2, 3, ...,s) in neighborhood i(i = 1, 2, 3, ...,N) in planning increment p(p = 1, 2, 3, ...,t).

Y_{ipk} = number of students transported from neighborhood i in planning increment p from school type k.

C_{ipk} = unit construction cost of constructing a school type k in neighborhood i in planning increment p.

M_{ipk} = maintenance cost of school type k in neighborhood i in planning increment p.

T_{ipk} = transportation cost of transporting students from school type k in neighborhood i in planning increment p.

subject to:

$$(2.1)\quad \sum_{i=1}^{N} \sum_{p=1}^{t} X_{ipk} = A_{ipk}$$ = minimum sq. ft. area to be constructed based on the anticipated enrollment at the end of the planning period for each school type k.

$$(2.1.1)\quad \sum_{i=1}^{N} X_{ipk}$$ = construction constraint determined by Table 8 for each k school type in each p planning increment.

$$(2.1.2)\quad \sum_{p=1}^{t} X_{ipk} \geq$$ minimum sq. ft. area as determined by enrollment for each neighborhood school.

(2.2.0) KX_{ipk} = anticipated enrollment at the end of planning increment one for each neighborhood and each school type k. K represents the reciprocal of the average square foot per student.

$K = 0.0118$ for $k = 1$

$K = 0.0095$ for $k = 2$

$K = 0.0108$ for $k = 3$

(2.2.1) $K\sum_{p=1}^{2} X_{ipk} + Y_{ipk}$ = anticipated enrollment at the end of planning increment two.

(2.2.2) $K\sum_{p=1}^{t} X_{ipk} + Y_{ipk}$ = anticipated enrollment at the end of the planning period.

(2.3) $X_{ipk} \geq 0$

(2.4) $Y_{ipk} \geq 0$

Reality

Of little concern thus far, has been the ability of a given study area to issue school bonds. The planner in search of the optimum plan must assume anything financial is possible when, in reality, it is not. The issuance of bonds is dependent upon the assessed valuation of the study area and laws governing the limit of bonded indebtedness of the study area. The school systems planner must be aware of this limit on his financial resources, and, as a minimum, provide a comparison between the optimal solution developed by the Model under the assumed and given conditions, and the actual assessed valuation of the respective study area, which is the basis for the issuance of school bonds. A necessary assumption for the development of the following equations is that the period of time for which the bonds are to be issued is equal to the length of the planning period in number of years. With that in mind, the relationship between bond revenue and assessed valuation may be expressed as in equation (3.0):

$$(3.0) \quad c_j = \left(\frac{p}{100}\right) Va$$

where:

c_j = face value of the anticipated bond issue which can be supported by the economy of the study area.

p = percent of allowable indebtedness prescribed by law for a particular study area.

Va = assessed valuation of the study area at the beginning of the planning period.

It would be presumptuous to assume that the face value of a bond issue represents the revenue which would be available to finance the new school system. As much as one third of the issue may be required for the retirement of the bonds and payment of interest. This leaves two thirds of the bond issue available for new school construction. The total school budget (B_t) may be approximated by equation (3.1):

$$(3.1) \quad B_t = \frac{2}{3} \left(\frac{p}{100} \right) Va$$

Given the total average budget, obtained from the model as the objective function, the assessed valuation of the study area necessary to obtain the desired level of education (assumed as optimal by the planner, community, and school systems planner) is expressed by equation (3.2):

$$(3.2) \quad Va = 1.5 \, B_t \left(\frac{100}{p} \right)$$

The feasibility of the model solution can thus be ascertained by comparing the actual assessed valuation of the study area with that required to support the proposed school system within the financial constraints outlined previously in this chapter. It may be necessary to reevaluate the budget constraints, specifically, the assumed School System Expenditure Pattern Curve, and adjust it to a pattern which would result in a lower total average budget. It may be advantageous to use the actual assessed valuation of the study area as the starting point for determining the initial total average budget (making $B_t = B_{ta}$), adjusting the total average expenditure on each school type k, (b_k), by proportionate shares. Using B_t as the maximum allowable school budget, and also as the area under the School System Expenditure Pattern Curve, an appropriate curve may be selected to yield a solution within the allowable limits of bonded indebtedness. This approach would have merit when a study area has an obviously substandard school system, coupled with a relatively low assessed valuation.

As an alternative to adjusting the budget constraints,should the bond issue be unable to finance the entire planned school system, other sources of revenue may be investigated such as an increase in taxes, soliciting of endowments, or, the inclusion of schools in Urban Renewal projects which are partially financed by the Federal Government.

The planner can not compromise his solution which provides for the minimum acceptable level of education for the community. The decisions concerning financing ultimately rests with the community. Community resistance to the school bond issue, higher taxes, etc., may however lead to the community's compromise of the planning solution. This is where salesmanship and politics play an important role. The public must be informed, have an enlightened awareness of the existing and anticipated problems, and exhibit an instilled community pride in a positive direction. An uninformed or misinformed public can lead to the demise of any system requiring community support for financial success. The planner has presented the needs of the community in his Comprehensive Development Plan. The school systems planner has presented his optimal solution to the school system needs consistent with the Plan and his Capital Budget. With the Community rests the realization of the goals of the Plan -- Reality.

CHAPTER IV

MODEL APPLICATION

Introduction

In order to apply the conceptual model to the Lake Charles Study Area, certain assumptions must necessarily be made. In that the primary data used was that developed by HNTB, the neighborhood analysis was assumed to be correct. The essential results of the analysis indicated that the following variables are equal to zero throughout the planning period due to the existence of adequate schools to serve the 1990 anticipated enrollments.

$X_{1p1} = 0$	$X_{1p2} = 0$	$X_{1p3} = 0$
$X_{5p1} = 0$	$X_{2p2} = 0$	$X_{2p3} = 0$
$X_{7p1} = 0$	$X_{3p2} = 0$	$X_{2p3} = 0$
$X_{10p1} = 0$	$X_{4p2} = 0$	$X_{4p3} = 0$
$X_{11p1} = 0$	$X_{5p2} = 0$	$X_{5p3} = 0$
$X_{12p1} = 0$	$X_{6p2} = 0$	$X_{6p3} = 0$
$X_{13p1} = 0$	$X_{7p2} = 0$	$X_{11p3} = 0$
$X_{14p1} = 0$	$X_{8p2} = 0$	$X_{13p3} = 0$
$X_{15p1} = 0$	$X_{9p2} = 0$	$X_{14p3} = 0$
$X_{16p1} = 0$	$X_{10p2} = 0$	$X_{15p3} = 0$
$X_{17p1} = 0$	$X_{12p2} = 0$	$X_{23p3} = 0$
$X_{18p1} = 0$	$X_{19p2} = 0$	$X_{24p3} = 0$

$X_{19p1} = 0$	$X_{20p2} = 0$	$X_{25p3} = 0$
$X_{20p1} = 0$	$X_{22p2} = 0$	$X_{26p3} = 0$
$X_{22p1} = 0$	$X_{23p2} = 0$	$X_{27p3} = 0$
$X_{23p1} = 0$	$X_{24p2} = 0$	
$X_{24p1} = 0$	$X_{25p2} = 0$	
$X_{25p1} = 0$	$X_{26p2} = 0$	
$X_{26p1} = 0$	$X_{27p2} = 0$	
$X_{30p1} = 0$	$X_{31p2} = 0$	
$X_{32p1} = 0$	$X_{32p2} = 0$	
$X_{33p1} = 0$	$X_{33p2} = 0$	
$X_{34p1} = 0$	$X_{34p2} = 0$	
$X_{36p1} = 0$	$X_{35p2} = 0$	

Model Restatement

The model, as applied to the Lake Charles Study Area, is expressed as equation (3.0)

$$(3.0) \qquad \text{Min:} \quad Z = \sum_{i=1}^{38} \sum_{p=1}^{4} \sum_{k=1}^{3} (C_{ipk} + M_{ipk})X_{ipk} + T_{ipk}Y_{ipk}$$

subject to:

(a) Area Constraints illustrated in tabular form in Tables 9.1, 9.2, and 9.3.

(b) Enrollment Constraints, Maintenance and Transportation constraints, and Minimum Construction Constraints illustrated in tabular form by planning increment in Tables 10.1.1, 10.1.2, 10.1.3, 10.2.1, 10.2.2, 10.2.3, 10.3.1, 10.3.2, 10.3.3, 10.4.1, 10.4.2, and 10.4.3.

Table 9.1

AREA CONSTRAINTS

PLANNING PERIOD
school type k=1

Planning Increment 1
X_{ipk}

Row Name	0211	0311	0411	0611	0811	0911	2111	2711	2811	2911	3111	3511	3711	3811
Area 02pl	1													
Area 03pl		1												
Area 04pl			1											
Area 06pl				1										
Area 08pl					1									
Area 09pl						1								
Area 21pl							1							
Area 27pl								1						
Area 28pl									1					
Area 29pl										1				
Area 31pl											1			
Area 35pl												1		
Area 37pl													1	
Area 38pl														1

Planning Increment 2
X_{ipk}

Row Name	0221	0321	0421	0621	0821	0921	2121	2721	2821	2921	3121	3521	3721	3821
Area 02pl	1													
Area 03pl		1												
Area 04pl			1											
Area 06pl				1										
Area 08pl					1									
Area 09pl						1								
Area 21pl							1							
Area 27pl								1						
Area 28pl									1					
Area 29pl										1				
Area 31pl											1			
Area 35pl												1		
Area 37pl													1	
Area 38pl														1

Table 9.1 (continued)

Planning Increment 3 X_{ipk}														Planning Increment 4 X_{ipk}															
0231	0331	0431	0631	0831	0931	2131	2731	2831	2931	3131	3531	3731	3831	0241	0341	0441	0641	0841	0941	2141	2741	2841	2941	3141	3541	3741	3841	Sign	Value
1														1														G	40,595
	1														1													G	49,780
		1														1												G	41,475
			1														1											G	28,440
				1														1										G	29,815
					1														1									G	51,705
						1														1								G	31,520
							1														1							G	49,835
								1														1						G	25,690
									1														1					G	80,915
										1														1				G	45,985
											1														1			G	54,125
												1														1		G	26,625
													1														1	G	25,000

Table 9.2

AREA CONSTRAINTS

PLANNING PERIOD
school type k=2

Row Name	Planning Increment 1 X_{ipk}														Planning Increment 2 X_{ipk}													
	1112	1312	1412	1512	1612	1712	1812	2112	2812	2912	3012	3612	3712	3812	1122	1322	1422	1522	1622	1722	1822	2122	2822	2922	3022	3622	3722	3822
Area 11p2	1														1													
Area 13p2		1														1												
Area 14p2			1														1											
Area 15p2				1														1										
Area 16p2					1														1									
Area 17p2						1														1								
Area 18p2							1														1							
Area 21p2								1														1						
Area 28p2									1														1					
Area 29p2										1														1				
Area 30p2											1														1			
Area 36p2												1														1		
Area 37p2													1														1	
Area 38p2														1														1

Table 9.2 (continued)

Planning Increment 3 X_{ipk}														Planning Increment 4 X_{ipk}															
1132	1332	1432	1532	1632	1732	1832	2132	2832	2932	3032	3632	3732	3832	1142	1342	1442	1542	1642	1742	1842	2142	2842	2942	3042	3642	3742	3842	Sign	Value
1														1														G	35,106
	1														1													G	32,259
		1														1												G	14,232
			1														1											G	13,283
				1														1										G	37,330
					1														1									G	27,758
						1														1								G	30,632
							1														1							G	17,095
								1														1						G	17,095
									1														1					G	50,280
										1														1				G	16,090
											1														1			G	36,000
												1														1		G	34,000
													1														1	G	30,000

Table 9.3

AREA CONSTRAINTS

PLANNING PERIOD
school type k=3

Planning Increment 1
X_{ipk}

Row Name	0713	0813	0913	1013	1213	2013	1613	1713	1813	1913	2113	2213	2813	2913	3013	3113	3213	3313	3413	3513	3613	3713	3813
Area 07p3	1																						
Area 08p3		1																					
Area 09p3			1																				
Area 10p3				1																			
Area 12p3					1																		
Area 20p3						1																	
Area 16p3							1																
Area 17p3								1															
Area 18p3									1														
Area 19p3										1													
Area 21p3											1												
Area 22p3												1											
Area 28p3													1										
Area 29p3														1									
Area 30p3															1								
Area 31p3																1							
Area 32p3																	1						
Area 33p3																		1					
Area 34p3																			1				
Area 35p3																				1			
Area 36p3																					1		
Area 37p3																						1	
Area 38p3																							1

Table 9.3 (continued)

Planning Increment 2

X_{ipk}

0723	0823	0923	1023	1223	2023	1623	1723	1823	1923	2123	2223	2823	2923	3023	3123	3223	3323	3423	3523	3623	3723	3823
1																						
	1																					
		1																				
			1																			
				1																		
					1																	
						1																
							1															
								1														
									1													
										1												
											1											
												1										
													1									
														1								
															1							
																1						
																	1					
																		1				
																			1			
																				1		
																					1	
																						1

Planning Increment 3

X_{ipk}

0733	0833	0933	1033	1233	2033	1633	1733	1833	1933	2133	2233	2833	2933	3033	3133	3233	3333	3433	3533	3633	3733	3833
1																						
	1																					
		1																				
			1																			
				1																		
					1																	
						1																
							1															
								1														
									1													
										1												
											1											
												1										
													1									
														1								
															1							
																1						
																	1					
																		1				
																			1			
																				1		
																					1	
																						1

Table 9.3 (continued)

Planning Increment 4

X_{ipk}

0743	0843	0943	1043	1243	2043	1643	1743	1843	1943	2143	2243	2843	2943	3043	3143	3243	3343	3443	3543	3643	3743	3843	Sign	Value
1																							G	24,851
	1																						G	15,022
		1																					G	34,679
			1																				G	27,378
				1																			G	20,498
					1																		G	17,972
						1																	G	34,083
							1																G	31,462
								1															G	36,705
									1														G	28,840
										1													G	13,922
											1												G	18,172
												1											G	9,965
													1										G	38,249
														1									G	12,457
															1								G	25,353
																1							G	28,431
																	1						G	58,015
																		1					G	26,485
																			1				G	41,620
																				1			G	51,250
																					1		G	41,250
																						1	G	32,500

Table 10.1.1

ENROLLMENT, CONSTRUCTION AND BUDGET CONSTRAINTS

PLANNING INCREMENT 1
school type k=1

Row Name	X_{i11}														Y_{i11}														Equality	Value
	0211	0311	0411	0611	0811	0911	2111	2711	2811	2911	3111	3511	3711	3811	0211	0311	0411	0611	0811	0911	2111	2711	2811	2911	3111	3511	3711	3811		
A01	1	1	1	1	1	1	1	1	1	1	1	1	1	1	a	a	a	a	a	a	a	a	a	a	a	a	a	a	L	435,740
A04	b														1														E	427
A05		b														1													E	589
A06			b														1												E	468
A07				b														1											E	184
A08					b														1										E	198
A09						b														1									E	476
A10							b														1								E	162
A11								b														1							E	370
A12									b														1						E	127
A13										b														1					E	387
A14											b														1				E	329
A15												b														1			E	324
A16													b														1		E	224
A17														b														1	E	128
E01	1	1	1	1	1	1	1	1	1	1	1	1	1	1															E	393,977

a = 20.5
b = 0.0118

Table 10.1.2

PLANNING INCREMENT 1
school type k=2

	X_{i12}														Y_{i12}															
Row Name	1112	1312	1412	1512	1612	1712	1812	2112	2812	2912	3012	3612	3712	3812	1112	1312	1412	1512	1612	1712	1812	2112	2812	2912	3012	3612	3712	3812	Equality	Value
A02	1	1	1	1	1	1	1	1	1	1	1	1	1	1	c	c	c	c	c	c	c	c	c	c	c	c	c	c	L	246,636
A18	d														1														E	324
A19		d														1													E	294
A20			d														1												E	140
A21				d														1											E	120
A22					d														1										E	155
A23						d														1									E	228
A24							d														1								E	278
A25								d														1							E	82
A26									d														1						E	64
A27										d														1					E	194
A28											d														1				E	58
A29												d														1			E	143
A30													d														1		E	112
A31														d														1	E	65
E02	1	1	1	1	1	1	1	1	1	1	1	1	1	1															E	230,585

c = 14.5
d = 0.0095

e = 14.5
f = 0.0108

PLANNING INCREMENT 1
school type k=3

X_{ipk}

Row Name	0713	0813	0913	1013	1213	2013	1613	1713	1813	1913	2113	2213	2813	2913	3013	3113	3213	3313	3413	3513	3613	3713	3813
A03	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
A32	f																						
A33		f																					
A34			f																				
A35				f																			
A36					f																		
A37						f																	
A38							f																
A39								f															
A40									f														
A41										f													
A42											f												
A43												f											
A44													f										
A45														f									
A46															f								
A47																f							
A48																	f						
A49																		f					
A50																			f				
A51																				f			
A52																					f		
A53																						f	
A54																							f
E03	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1

Table 10.1.3 (continued)

Y_{1pk}																								
0713	0813	0913	1013	1213	2013	1613	1713	1813	1913	2113	2213	2813	2913	3013	3113	3213	3313	3413	3513	3613	3713	3813	Sign	Value
e	e	e	e	e	e	e	e	e	e	e	e	e	e	e	e	e	e	e	e	e	e	e	L	458,468
1																							E	141
	1																						E	89
		1																					E	238
			1																				E	212
				1																			E	172
					1																		E	144
						1																	E	154
							1																E	227
								1															E	277
									1														E	206
										1													E	81
											1												E	106
												1											E	64
													1										E	193
														1									E	57
															1								E	164
																1							E	128
																	1						E	339
																		1					E	102
																			1				E	162
																				1			E	143
																					1		E	111
																						1	E	64
																							E	432,378

Table 10.2.1

PLANNING INCREMENT 2
school type k=1

Row Name	X_{i11} 0211	0311	0411	0611	0811	0911	2111	2711	2811	2911	3111	3511	3711	3811	X_{i21} 0221	0321	0421	0621	0821	0921	2121	2721	2821	2921	3121	3521	3721	3821
B01	g	g	g	g	g	g	g	g	g	g	g	g	g	g	1	1	1	1	1	1	1	1	1	1	1	1	1	1
B04	b														b													
B05		b														b												
B06			b														b											
B07				b														b										
B08					b														b									
B09						b														b								
B10							b														b							
B11								b														b						
B12									b														b					
B13										b														b				
B14											b														b			
B15												b														b		
B16													b														b	
B17														b														b
E04															1	1	1	1	1	1	1	1	1	1	1	1	1	1

b = 0.0118
g = 0.04
h = 19.5

Table 10.2.1 (continued)

Y_{121}															
0221	0321	0421	0621	0821	0921	2121	2721	2821	2921	3121	3521	3721	3821	Sign	Value
h	h	h	h	h	h	h	h	h	h	h	h	h	h	L	176,168
1														E	451
	1													E	652
		1												E	485
			1											E	227
				1										E	230
					1									E	545
						1								E	213
							1							E	456
								1						E	158
									1					E	521
										1				E	406
											1			E	441
												1		E	285
													1	E	155
														E	135,854

Table 10.2.2

PLANNING INCREMENT 2
school type k=2

Row Name	X_{112}														X_{122}													
	1112	1312	1412	1512	1612	1712	1812	2112	2812	2912	3012	3612	3712	3812	1122	1322	1422	1522	1622	1722	1822	2122	2822	2922	3022	3622	3722	3822
B02	g	g	g	g	g	g	g	g	g	g	g	g	g	g	1	1	1	1	1	1	1	1	1	1	1	1	1	1
B18	d														d													
B19		d														d												
B20			d														d											
B21				d														d										
B22					d														d									
B23						d														d								
B24							d														d							
B25								d														d						
B26									d														d					
B27										d														d				
B28											d														d			
B29												d														d		
B30													d														d	
B31														d														d
E05															1	1	1	1	1	1	1	1	1	1	1	1	1	1

d = 0.0095
g = 0.04
m = 13.5

Table 10.2.2 (continued)

Y_{i22}															
1122	1322	1422	1522	1622	1722	1822	2122	2822	2922	3022	3622	3722	3822	Sign	Value
m	m	m	m	m	m	m	m	m	m	m	m	m	m	L	97,297
1														E	325
	1													E	296
		1												E	129
			1											E	122
				1										E	220
					1									E	237
						1								E	282
							1							E	106
								1						E	79
									1					E	260
										1				E	83
											1			E	123
												1		E	141
													1	E	78
														E	79,512

$f = 0.0108$
$g = 0.04$
$j = 13.5$

PLANNING INCREMENT 2
school type k=3

X_{113}

Row Name	0713	0813	0913	1013	1313	2013	1613	1713	1813	1913	2113	2213	2813	2913	3013	3113	3213	3313	3413	3513	3613	3713	3813
B03	g	g	g	g	g	g	g	g	g	g	g	g	g	g	g	g	g	g	g	g	g	g	g
B32	f																						
B33		f																					
B34			f																				
B35				f																			
B36					f																		
B37						f																	
B38							f																
B39								f															
B40									f														
B41										f													
B42											f												
B43												f											
B44													f										
B45														f									
B46															f								
B47																f							
B48																	f						
B49																		f					
B50																			f				
B51																				f			
B52																					f		
B53																						f	
B54																							f
E06																							

Table 10.2.3 (continued)

X_{123}

0723	0823	0923	1023	1223	2023	1623	1723	1823	1923	2123	2223	2823	2923	3023	3123	3223	3323	3423	3523	3623	3723	3823
1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
f																						
	f																					
		f																				
			f																			
				f																		
					f																	
						f																
							f															
								f														
									f													
										f												
											f											
												f										
													f									
														f								
															f							
																f						
																	f					
																		f				
																			f			
																				f		
																					f	
																						f
1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1

Table 10.2.3 (continued)

Y_{123}																								
0723	0823	0923	1023	1223	2023	1623	1723	1823	1923	2123	2223	2823	2923	3023	3123	3223	3323	3423	3523	3623	3723	3823	Sign	Value
j	j	j	j	j	j	j	j	j	j	j	j	j	j	j	j	j	j	j	j	j	j	j	L	181,140
1																							E	178
	1																						E	114
		1																					E	272
			1																				E	228
				1																			E	179
					1																		E	153
						1																	E	219
							1																E	236
								1															E	281
									1														E	212
										1													E	106
											1												E	138
												1											E	79
													1										E	260
														1									E	82
															1								E	203
																1							E	198
																	1						E	373
																		1					E	142
																			1				E	220
																				1			E	122
																					1		E	141
																						1	E	77
																							E	149,096

Table 10.3.1

PLANNING INCREMENT 3
school type k=1

	X_{i11}														X_{i21}													
Row Name	0211	0311	0411	0611	0811	0911	2111	2711	2811	2911	3111	3511	3711	3811	0221	0321	0421	0621	0821	0921	2121	2721	2821	2921	3121	3521	3721	3821
C01	n	n	n	n	n	n	n	n	n	n	n	n	n	n	p	p	p	p	p	p	p	p	p	p	p	p	p	p
C04	b														b													
C05		b														b												
C06			b														b											
C07				b														b										
C08					b														b									
C09						b														b								
C10							b														b							
C11								b														b						
C12									b														b					
C13										b														b				
C14											b														b			
C15												b														b		
C16													b														b	
C17														b														b
E07																												

b = 0.0118
n = 0.08
p = 0.05
q = 18.0

Table 10.3.1 (continued)

X_{i31}														Y_{i31}															
0231	0331	0431	0631	0831	0931	2131	2731	2831	2931	3131	3531	3731	3831	0231	0331	0431	0631	0831	0931	2131	2731	2831	2931	3131	3531	3731	3831	Sign	Value
1	1	1	1	1	1	1	1	1	1	1	1	1	1	q	q	q	q	q	q	q	q	q	q	q	q	q	q	L	132,469
b														1														E	481
	b														1													E	665
		b														1												E	506
			b														1											E	258
				b														1										E	269
					b														1									E	623
						b														1								E	275
							b														1							E	567
								b														1						E	196
									b														1					E	755
										b														1				E	501
											b														1			E	589
												b														1		E	244
													b														1	E	187
1	1	1	1	1	1	1	1	1	1	1	1	1	1															E	81,512

Table 10.3.2

PLANNING INCREMENT 3
school type k=2

Row Name	X_{112}														X_{122}													
	1112	1312	1412	1512	1612	1712	1812	2112	2812	2912	3012	3612	3712	3812	1122	1322	1422	1522	1622	1722	1822	2122	2822	2922	3022	3622	3722	3822
C02	n	n	n	n	n	n	n	n	n	n	n	n	n	n	p	p	p	p	p	p	p	p	p	p	p	p	p	p
C18	d														d													
C19		d														d												
C20			d														d											
C21				d														d										
C22					d														d									
C23						d														d								
C24							d														d							
C25								d														d						
C26									d														d					
C27										d														d				
C28											d														d			
C29												d														d		
C30													d														d	
C31														d														d
E08																												

Table 10.3.2 (continued)

X_{i32}														Y_{i32}															
1132	1332	1432	1532	1632	1732	1832	2132	2832	2932	3032	3632	3732	3832	1132	1332	1432	1532	1632	1732	1832	2132	2832	2932	3032	3632	3732	3832	Sign	Value
1	1	1	1	1	1	1	1	1	1	1	1	1	1	R	R	R	R	R	R	R	R	R	R	R	R	R	R	L	74,558
d														1														E	326
	d														1													E	296
		d														1												E	128
			d														1											E	122
				d														1										E	270
					d														1									E	250
						d														1								E	286
							d														1							E	137
								d														1						E	98
									d														1					E	378
										d														1				E	124
											d														1			E	153
												d														1		E	122
													d														1	E	93
1	1	1	1	1	1	1	1	1	1	1	1	1	1															E	47,707

n = 0.08
p = 0.05
s = 13.0

PLANNING INCREMENT 3
school type k=3

X_{i13}

Row Name	0713	0813	0913	1013	1213	2013	1613	1713	1813	1913	2113	2213	2813	2913	3013	3113	3213	3313	3413	3513	3613	3713	3813
C03	n	n	n	n	n	n	n	n	n	n	n	n	n	n	n	n	n	n	n	n	n	n	n
C32	f																						
C33		f																					
C34			f																				
C35				f																			
C36					f																		
C37						f																	
C38							f																
C39								f															
C40									f														
C41										f													
C42											f												
C43												f											
C44													f										
C45														f									
C46															f								
C47																f							
C48																	f						
C49																		f					
C50																			f				
C51																				f			
C52																					f		
C53																						f	
C54																							f
E09																							

Table 10.3.3 (continued)

X_{123}

0723	0823	0923	1023	1223	2023	1623	1723	1823	1923	2123	2223	2823	2923	3023	3123	3223	3323	3423	3523	3623	3723	3823
p	p	p	p	p	p	p	p	p	p	p	p	p	p	p	p	p	p	p	p	p	p	p
f																						
	f																					
		f																				
			f																			
				f																		
					f																	
						f																
							f															
								f														
									f													
										f												
											f											
												f										
													f									
														f								
															f							
																f						
																	f					
																		f				
																			f			
																				f		
																					f	
																						f

X_{133}

0733	0833	0933	1033	1233	2033	1633	1733	1833	1933	2133	2233	2833	2933	3033	3133	3233	3333	3433	3533	3633	3733	3833
1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
f																						
	f																					
		f																				
			f																			
				f																		
					f																	
						f																
							f															
								f														
									f													
										f												
											f											
												f										
													f									
														f								
															f							
																f						
																	f					
																		f				
																			f			
																				f		
																					f	
																						f
1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1

Table 10.3.3 (continued)

Y_{133}																								
0733	0833	0933	1033	1233	2033	1633	1733	1833	1933	2133	2233	2833	2933	3033	3133	3233	3333	3433	3533	3633	3733	3833	Sign	Value
S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	L	139,792
1																							E	224
	1																						E	134
		1																					E	311
			1																				E	246
				1																			E	184
					1																		E	161
						1																	E	270
							1																E	249
								1															E	286
									1														E	221
										1													E	137
											1												E	180
												1											E	98
													1										E	377
														1									E	124
															1								E	250
																1							E	281
																	1						E	418
																		1					E	191
																			1				E	294
																				1			E	152
																					1		E	122
																						1	E	93
																							E	89,458

Table 10.4.1

PLANNING INCREMENT 4
school type k=1

Row Name	X_{111}														X_{121}													
	0211	0311	0411	0611	0811	0911	2111	2711	2811	2911	3111	3511	3711	3811	0221	0321	0421	0621	0821	0921	2121	2721	2821	2921	3121	3521	3721	3821
D01	t	t	t	t	t	t	t	t	t	t	t	t	t	t	u	u	u	u	u	u	u	u	u	u	u	u	u	u
D04	b														b													
D05		b														b												
D06			b														b											
D07				b														b										
D08					b														b									
D09						b														b								
D10							b														b							
D11								b														b						
D12									b														b					
D13										b														b				
D14											b														b			
D15												b														b		
D16													b														b	
D17														b														b
E10																												

b = 0.0118
t = 0.13
u = 0.10
v = 0.06
w = 17.0

Table 10.4.1 (continued)

X_{131}														X_{141}													
0231	0331	0431	0631	0831	0931	2131	2731	2831	2931	3131	3531	3731	3831	0241	0341	0441	0641	0841	0941	2141	2741	2841	2941	3141	3541	3741	3841
v	v	v	v	v	v	v	v	v	v	v	v	v	v	1	1	1	1	1	1	1	1	1	1	1	1	1	1
b														b													
	b														b												
		b														b											
			b														b										
				b														b									
					b														b								
						b														b							
							b														b						
								b														b					
									b														b				
										b														b			
											b														b		
												b														b	
													b														b
														1	1	1	1	1	1	1	1	1	1	1	1	1	1

Table 10.4.1 (continued)

Y_{141}															
0241	0341	0441	0641	0841	0941	2141	2741	2841	2941	3141	3541	3741	3841	Sign	Value
W	W	W	W	W	W	W	W	W	W	W	W	W	W	L	139,318
1														E	509
	1													E	676
		1												E	525
			1											E	288
				1										E	313
					1									E	711
						1								E	344
							1							E	677
								1						E	238
									1					E	1,013
										1				E	607
											1			E	755
												1		E	255
													1	E	220
														E	67,927

Table 10.4.2

PLANNING INCREMENT 4
school type k=2

X_{112}

Row Name	1112	1312	1412	1512	1612	1712	1812	2112	2812	2912	3012	3612	3712	3812
D02	t	t	t	t	t	t	t	t	t	t	t	t	t	t
D18	d													
D19		d												
D20			d											
D21				d										
D22					d									
D23						d								
D24							d							
D25								d						
D26									d					
D27										d				
D28											d			
D29												d		
D30													d	
D31														d
E11														

X_{122}

Row Name	1122	1322	1422	1522	1622	1722	1822	2122	2822	2922	3022	3622	3722	3822
D02	u	u	u	u	u	u	u	u	u	u	u	u	u	u
D18	d													
D19		d												
D20			d											
D21				d										
D22					d									
D23						d								
D24							d							
D25								d						
D26									d					
D27										d				
D28											d			
D29												d		
D30													d	
D31														d
E11														

d = 0.0095
t = 0.13
u = 0.10
v = 0.06
x = 12.0

Table 10.4.2 (continued)

X_{i32}														X_{i42}													
1132	1332	1432	1532	1632	1732	1832	2132	2832	2932	3032	3632	3732	3832	1142	1342	1442	1542	1642	1742	1842	2142	2842	2942	3042	3642	3742	3842
v	v	v	v	v	v	v	v	v	v	v	v	v	v	1	1	1	1	1	1	1	1	1	1	1	1	1	1
d														d													
	d														d												
		d														d											
			d														d										
				d														d									
					d														d								
						d														d							
							d														d						
								d														d					
									d														d				
										d														d			
											d														d		
												d														d	
													d														d
														1	1	1	1	1	1	1	1	1	1	1	1	1	1

Table 10.4.2 (continued)

Y_{i42}															
1142	1342	1442	1542	1642	1742	1842	2142	2842	2942	3042	3642	3742	3842	Sign	Value
x	x	x	x	x	x	x	x	x	x	x	x	x	x	L	81,539
1														E	325
	1													E	297
		1												E	127
			1											E	123
				1										E	344
					1									E	258
						1								E	291
							1							E	172
								1						E	169
									1					E	507
										1				E	166
											1			E	134
												1		E	128
													1	E	110
														E	39,756

t = 0.13
u = 0.10
v = 0.06
z = 12.0

PLANNING INCREMENT 4
school type k=3

Row Name	X_{113}																							X_{123}																						
	0713	0813	0913	1013	1213	2013	1613	1713	1813	1913	2113	2213	2813	2913	3013	3113	3213	3313	3413	3513	3613	3713	3813	0723	0823	0923	1023	1223	2023	1623	1723	1823	1923	2123	2223	2823	2923	3023	3123	3223	3323	3423	3523	3623	3723	3823
D03	t	t	t	t	t	t	t	t	t	t	t	t	t	t	t	t	t	t	t	t	t	t	t	u	u	u	u	u	u	u	u	u	u	u	u	u	u	u	u	u	u	u	u	u	u	u
D32	f																							f																						
D33		f																							f																					
D34			f																							f																				
D35				f																							f																			
D36					f																							f																		
D37						f																							f																	
D38							f																							f																
D39								f																							f															
D40									f																							f														
D41										f																							f													
D42											f																							f												
D43												f																							f											
D44													f																							f										
D45														f																							f									
D46															f																							f								
D47																f																							f							
D48																	f																							f						
D49																		f																							f					
D50																			f																							f				
D51																				f																							f			
D52																					f																							f		
D53																						f																							f	
D54																							f																							f
E12																																														

Table 10.4.3 (continued)

X_{133}																						
0733	0833	0933	1033	1233	2033	1633	1733	1833	1933	2133	2233	2833	2933	3033	3133	3233	3333	3433	3533	3633	3733	3833
v	v	v	v	v	v	v	v	v	v	v	v	v	v	v	v	v	v	v	v	v	v	v
f																						
	f																					
		f																				
			f																			
				f																		
					f																	
						f																
							f															
								f														
									f													
										f												
											f											
												f										
													f									
														f								
															f							
																f						
																	f					
																		f				
																			f			
																				f		
																					f	
																						f

X_{143}																						
0743	0843	0943	1043	1243	2043	1643	1743	1843	1943	2143	2243	2843	2943	3043	3143	3243	3343	3443	3543	3643	3743	3843
1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
f																						
	f																					
		f																				
			f																			
				f																		
					f																	
						f																
							f															
								f														
									f													
										f												
											f											
												f										
													f									
														f								
															f							
																f						
																	f					
																		f				
																			f			
																				f		
																					f	
																						f
1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1

Table 10.4.3 (continued)

Y_{143}																								
0743	0843	0943	1043	1243	2043	1643	1743	1843	1943	2143	2243	2843	2943	3043	3143	3243	3343	3443	3543	3643	3743	3843	Sign	Value
z	z	z	z	z	z	z	z	z	z	z	z	z	z	z	z	z	z	z	z	z	z	z	L	151,220
1																							E	275
	1																						E	156
		1																					E	355
			1																				E	265
				1																			E	190
					1																		E	171
						1																	E	343
							1																E	257
								1															E	290
									1														E	229
										1													E	172
											1												E	225
												1											E	169
													1										E	506
														1									E	165
															1								E	303
																1							E	382
																	1						E	463
																		1					E	248
																			1				E	377
																				1			E	133
																					1		E	127
																						1	E	109
																							E	74,548

Model Application

The model was first run on the IBM 360 computer without the constraints enumerated as row name E01 thru E12 in Tables 10.1.1 thru 10.4.3. The results were somewhat as expected in that essentially the computer indicated that every school should be built whenever money was available. In essence, the cost of transporting pupils far exceeds its trade-off factor of maintenance cost -- thus the entire projected school system should be built during the first planning period. If this were possible, the school board would be operating at its minimal school budget level since all costs (construction, maintenance, and transportation) are increasing at varying rates from the first planning increment to the last planning increment. Obviously, this is not a feasible solution to the problem.

As such, the constraints enumerated in row names E01 thru E12 were developed to place a limit on construction within each planning increment. These constraints also resulted in an infeasible solution statement by the computer program. It is hypothesized that the range of feasibility was severely limited by these row constraints. Thus succeeding runs were made with increased limits to these specific rows. This, however, did not yield a feasible solution either. Thus an investigation was made of the equalities and inequalities within the formulation of the constraints and no rationale could be developed for changing the formulation. The Area constraints developed should be an equality, and the enrollment constraints are based on projections and as such should be either a minimum or an equality in the sense that as a minimization problem, the lowest cost would be associated with the minimum enrollment. The Construction constraints per planning increment (Rows E01 thru E12) are, in essence, an equality based upon how the school board would like to balance out total construction per school type per planning increment. This leaves only the initial construction constraints enumerated by Rows A01 thru A03, B01 thru B03, C01 thru C03 and D01 thru D03 in Tables 10.1.1 thru 10.4.3 as suspect. These constraints offer basically the only trade-offs in the model: Transportation Costs vs Maintenance Cost plus Construction Costs.

CHAPTER V

CONCLUSION

Model Analysis

In trying to ascertain the problems relating to the development of this paper, it is necessary to review the various assumptions made in the initial model formulation. In the opening statements of Chapter III, a statement was made indicating that school construction is solely dependent on when the neighborhood, community, or school district could economically support that school with a minimum enrollment. This statement formed the basis for one constraint formulation (minimum enrollments) which may be in error. School Construction is not solely dependent on enrollment. There, obviously, must be a plan which will balance out enrollment in the various neighborhoods with an optimal end plan, which may never occur due to the inability of the school boards to control all development within their district. This is not to say that they should be able to control development, but that they offer services to an unknown and changing population over which they have no control. As such, another constraint with which the school board must contend, is the economic necessity of obtaining bond approval through the general election framework before being able to issue bonds or even plan for new school construction.

Another likely source of problems is in the determination of maintenance costs. A review of the Wichita/Sedgewick County School District Budget for the years 1966 to 1971 has indicated that the budget for the maintenance of their school plants varied drastically from year to year, and in a sporadic manner such that no trend could be determined. It is hypothesized that of all the costs of running a school plant, maintenance costs would be most easily cut should it be necessary to work within a fixed budget predetermined by the municipality. In essence, maintenance costs may not be the most appropriate indicator to balance against Transportation Costs.

A comparison of Maintenance Cost per student (estimated in a linear fashion disregarding the major fluctuations cited previously) and transportation costs per student indicates that the differences are so great as to preclude their use in the manner used as balancing constraints. The high cost of transporting students would indicate, in the long run, that school construction should be immediate to serve the existing and future population, rather than spend the financial resources on bussing and then be short of the financial resources to build the school later.

The concept of linear programming as applied to capital budgeting and school construction has a great deal of merit in that the parameters are based on real numbers and can thus be evaluated. A reasonable approximation for use by planners in locating schools is to establish an equal or nearly equal financial school construction phasing schedule, based on community need for the school, and limits of bonded indebtedness. School enrollments, construction costs, city valuations, etc. can be correctly obtained and projected from existing data sources. Once completed, it remains a relatively minor task to assign schools on a financial basis coupled with development standards, rather than merely on a standard set forth for the entire country.

In assessing the utility of the model to the planner, one should recall the number of normative judgements a planner must make. Any such model which will accelerate the planning process ultimately frees the planner to concentrate on other aspects of the objective comprehensive plan. The model, as designed, requires work beyond the capability of the author and should be regarded as conceptual in its entirety. Conceptually, it should allocate schools to a specific neighborhood or district. The judgement of precisely where within that neighborhood or district still belongs to the planner.

The utility of the model for school administrators and budget officials lies not in the model, itself, but in the objective plan developed by the planner. The planning for schools based on knowledge that it can be funded, rather than on the basis of a general standard applied to a given school system, adds a touch of realism to an otherwise utopian situation.

Unfortunately, many legislators and government officials look on planning as an "idealistic state" because of lack of realism in its scope and context. Master Plans and City Plans are being completed all over the world--plans which are making good additions to overflowing bookshelves because of the unrealistic adaption of "standards" and lack of financial backing to implement the basic plan.

The technique as set forth on these pages, hopefully, will create a cost awareness in evaluating, at least, one of the many variables which, together, form the basis of Master Planning today and tomorrow.

FOOTNOTES

[1]Metropolitan Dade County Planning Advisory Board and the Metropolitan Dade County Planning Department, Preliminary Land Use Plan and Policies for Development, prepared for the Board of County Commissioners, Metropolitan Dade County (Miami: 1961).

[2]F. Stuart Chapin, Jr. "A Model For Simulating Residential Development," Journal of the American Institute of Planners, XXXI (May, 1965), 121.

[3]F. Stuart Chapin, Jr. Urban Land Use Planning. 2nd ed. Urbana: University of Illinois Press, 1965. p. 473.

[4]Britton Harris, "A Gloss On Lacklustre Terms," Journal of the American Institute of Planners, XXXI (May, 1965), pp. 94-95.

[5]Jesse Burkhead, "The Capital Budget," Government Budgeting. John Wiley and Sons, Inc., 1956. p. 182.

[6]Jesse Burkhead, State and Local Taxes for Public Education, Syracuse University Press, 1963, pp. 103-104.

[7]Ibid.

[8]Chapin, Urban Land Use Planning, loc. cit.

[9]Walter G. Hansen, "How Accessibility Shapes Land Use," Journal of The American Institute of Planners, (May, 1959).

[10]Chapin, Urban Land Use Planning, op. cit., p. 479.

[11]T. R. Lakshmanan and Margaret E. Fry, "An Approach to the Analysis of Intraurban Location," a paper presented at the annual meetings of the Southeastern Section, Regional Science Association, November, 1963.

[12]T. R. Lakshmanan and Walter G. Hansen. "A Retail Market Potential Model," Journal of The American Institute of Planners, XXXI (May, 1965), pp. 134-143.

[13]George T. Lathrop and John R. Hamburg. "An Opportunity-Accessibility Model for Allocating Regional Growth," Journal of The American Institute of Planners, XXXI, (May, 1965), pp. 95-103.

[14]Donald M. Hill, "A Growth Allocation Model for the Boston Region," *Journal of The American Institute of Planners*, XXXI, (May, 1965), pp. 111-120.

[15]Ira S. Lowry, *A Model of Metropolis*, (The Rand Corporation Rand Research Memorandum RM-4035-RC, August, 1964).

[16]Wilbur A. Steger, "The Pittsburgh Urban Renewal Simulation Model," *Journal of The American Institute of Planners*, XXXI, (May, 1965), pp. 144-149.

[17]John D. Herbert and Benjamin H. Stevens, "A Model for the Distribution of Residential Activity in Urban Areas," *Journal of Regional Science*, Fall, 1960.

[18]Chapin, A Model, *op. cit.*, pp. 120-125.

[19]Ira M. Robinson, Harry B. Wolfe, and Robert L. Barringer. "A Simulation Model for Renewal Programming," *Journal of The American Institute of Planners*, XXXI, (May, 1965) pp. 126-133.

[20]Kenneth J. Schlager, "A Report on Models of the Southeastern Wisconsin Regional Planning Commission," *Newsletter of the Transportation Planning Computer Program Exchange Group*, Vol. 1, No. 2, Washington: U.S. Bureau of Public Roads, (October 15, 1963).

[21]W. W. Leontief, "Input - Output Economics," *Scientific American*, Vol. 185, (1951).

[22]Benjamin H. Stevens, "A Review of the Literature on Linear Methods and Models for Spatial Analysis", *Journal of The American Institute of Planners*, XXVI, (February, 1960) pp. 253-257.

[23]Walter Isard, "Interregional Linear Programming: An Elementary Presentation and a General Model," *Journal of Regional Science*, I, 1 (Summer, 1958), pp. 1-59.

[24]Kenneth J. Schlager, "A Land Use Plan Model," *Journal of The American Institute of Planners*, XXXI (May, 1965), pp. 103-111.

[25]Basil Castaldi. *Creative Planning of Educational Facilities*. Rand McNally & Company, Chicago, Illinois, 1969. pp. 330-332.

[26] *Ibid*. p. 174

[27] *Ibid*. p. 226

[28] E. Glenn Featherston and D. P. Culp. -"Pupil Transportation" Harper & Row, New York, Evanston and London, 1965.

[29] *Ibid*. p. 6

REFERENCES

Books

Burkhead, Jesse. State and Local Taxes for Public Education. Syracuse University. 1963.

________, "The Capital Budget," Government Budgeting. John Wiley & Sons, Inc., 1956.

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

Chapin, F. Stuart, Jr., Urban Land Use Planning. 2nd ed. Urbana: University of Illinois Press, 1965.

Featherson, E. Glenn, and D. P. Culp. Pupil Transportation. New York: Harper & Row, 1965.

Garvin, Walter W., Introduction to Linear Programming. New York: McGraw-Hill Book Company, Inc., 1960.

International City Managers Association, Principles and Practice of Urban Planning, 4th ed. The Municipal Management Series: 1968.

Isard, Walter, Methods of Regional Analysis: An Introduction to Regional Science. MIT Press and John Wiley & Sons, Inc., New York, 1960.

Lev, Donald J. Planning Educational Facilities. New York: Center for Applied Research in Education, Inc., 1965.

Lowry, Ira S. "Seven Models of Urban Development: A Structural Comparison," Urban Development Models, Highway Research Board: Special Report 97, (Washington D.C., 1968).

MacConnell, James D. Planning for School Buildings. Prentice-Hall, Inc., 1957.

Weingartner, H. Martin. Mathematical Programming and the Analysis of Capital Budgeting Problems. Prentice-Hall, Inc., 1964.

Reports

Metropolitan Dade County Planning Advisory Board and the Metropolitan Dade County Planning Department, Preliminary Land Use Plan and Policies for Development, prepared for the Board of County Commissioners, Metropolitan Dade County (Miami: 1961).

Howard, Needles, Tammen & Bergendoff, Population and Economy, Lake Charles Metropolitan Area Transportation Study, Technical Study No. 1. Kansas City, Missouri: August, 1966.

_______, Metropolitan Plan, Lake Charles Metropolitan Area Transportation Study, Technical Study No. 2. Kansas City, Missouri: December, 1966.

_______, Financial Resources, Lake Charles Metropolitan Area Transportation Study, Technical Study No. 3. Kansas City, Missouri: February, 1967.

Kansas City, Missouri School District. School Facts: Annual Report of the Superintendent of Schools, Report No. 19. June, 1966.

Articles

Barnard, Boyd T., "Standards for New Urban Development -- The Denver Background," Urban Land, Vol. 20, No. 5. Urban Land Institute, (May, 1961), 1-8.

Chapin, F. Stuart, Jr., "A Model for Simulating Residential Development," Journal of the American Institute of Planners, XXXI (May, 1965).

________. "Selected Theories of Urban Growth and Structure," Journal of the American Institute of Planners, XXX (February, 1964), 51-59.

Cooper, Wm. W. and Abraham Charnes. "Linear Programming," Scientific American, Vol. 19 (August, 1954), 21-23.

Hansen, Walter G. "How Accessibility Shapes Land Use," Journal of the American Institute of Planners, XXV (May, 1959).

Harris, Britton. "A Gloss on Lacklustre Terms," Journal of the American Institute of Planners, XXXI (May, 1965), 94-95.

Herbert, John D. and Benjamin H. Stevens. "A Model for the Distribution of Residential Activity in Urban Areas," Journal of Regional Science, (Fall, 1960).

Hill, Donald M. "A Growth Allocation Model for the Boston Region," Journal of the American Institute of Planners, XXXI (May, 1965), 111-120.

Isard, Walter. "Interregional Linear Programming: An Elementary Presentation and a General Model," Journal of Regional Science, (Summer, 1958), 1-59.

Lackshmanan, T. R. and Margaret E. Fry. "An Approach to the Analysis of Intraurban Location," A paper presented at the Annual meetings of the Southeastern Section, Regional Science Association, (November, 1963).

Lakshmanan, T. R. and Walter G. Hansen. " A Retail Market Potential Model," Journal of the American Institute of Planners, XXXI (May, 1965), 134-143.

Lathrop, George T. and John R. Hamburg. "An Opportunity-Accessibility Model for Allocating Regional Growth," Journal of the American Institute of Planners, XXXI (May, 1965), 95-103.

Leontief, W. W. "Input-Output Economics," Scientific American, Vol. 185, (1951).

Litchfield, Nathaniel. "Cost-Benefit Analysis in City Planning," Journal of the American Institute of Planners, XXVI (November, 1960), 273-279.

Lowry, Ira S. "A Model of Metropolis," The Rand Corporation, Rand Research Memorandum RM-4035-RC, (August, 1964).

<u>Articles</u> (cont.)

McLaughlin, James F. "Application of Linear Programming to Urban Planning" (Thesis Abstract and Bibliography) <u>Council of Planning Librarians</u>, Exchange Bibliography 45, (April, 1968).

Robinson, Ira. M., Harry B. Wolfe, and Robert L. Barringer. "A Simulation Model for Renewal Programming," <u>Journal of the American Institute of Planners</u>, XXXI (May, 1965), 126-133.

Schlager, Kenneth J. "A Land Use Plan Model," <u>Journal of the American Institute of Planners</u>, XXXI (May, 1965), 103-111.

________. "A Report on Models of the Southeastern Wisconsin Regional Planning Commission," <u>Newsletter of the Transportation Planning Computer Program Exchange Group</u>, Vol. 1, No. 2, Washington: U. S. Bureau of Public Roads, (October, 1963).

Spivey, W. Allen. "Linear Programming," <u>Science</u>, Vol. 135, No. 3497 (January, 1962), 23-27.

Steger, Wilbur A. "The Pittsburgh Urban Renewal Simulation Model," <u>Journal of the American Institute of Planners</u>, XXXI (May, 1965), 144-149.

Stevens, Benjamin H. "A Review of the Literature on Linear Methods and Models for Spatial Analysis," <u>Journal of the American Institute of Planners</u>, XXVI (February, 1960), 253-257.

Other Sources

Kansas City, Missouri Board of Education. Personal Interview with G. Dewey Smith, Business Manager. October 20, 1966.

Wyandotte County School District, Kansas City, Kansas. Personal Interview with H. L. Brotherson, Business Manager. November 3, 1966.

APPENDIX A

Basic Standards for New Urban Development
Urban Land Institute
May 1961

I. ASSUMPTIONS

1. Average Family Size:
   (a) For purposes of schools planning: 4.4 persons per dwelling unit.
   (b) For purposes of land use and public services and facilities planning: 3.8 persons per dwelling.
2. Age Distribution of Population:

Age Group	Distribution in New Residential Subdivisions* (For Schools Planning) No. Per Dwelling Unit	Percent of Total Pop.	Distribution in Established Residential Community No. Per Dwelling Unit	Percent of Total Pop.	Distribution in a Metropolitan Region** No. Per Dwelling Unit	Total Pop.
Pre-School	0.75	17.0	0.47	12.3	0.38	11.2
Kindergarten	0.15	3.4	0.09	2.4	0.07	2.1
Elementary School	0.85	19.3	0.52	13.7	0.41	12.0
Junior High School	0.25	5.7	0.20	5.3	0.17	5.0
Senior High School	0.23	5.2	0.19	5.0	0.16	4.7
Working Age	2.07	47.1	2.09	55.0	1.91	56.2
Retired (over 65)	0.10	2.3	0.24	6.3	0.30	8.8
	4.40		3.80		3.40	

II. DEFINITIONS

1. Neighborhood — An area served by one elementary school, usually bounded by major or secondary streets, or other natural or artificial boundaries; population between 3,000 and 5,000 for average densities.

	by major natural or man-made boundaries; population between 30,000 and 40,000.
3. District/Region	An area of two or more communities: 75,000 or more population.

III. SCHOOLS

School Type	Minimum Size	Ideal Size	Maximum Size	Site Size	Radius of Area Served
	(pupils)	(pupils)	(pupils)	(acres)	(miles)
Elementary	230	700	900	5 + 1 per 100 pupils	0.5
Junior High	750	1,000	1,500	15 + 1 per 100 pupils	1.0
Senior High	900	1,500	2,500	25 + 1 per 100 pupils	2.0
Elementary-Junior High Combination				15 + 1 per 100 pupils	1.0
Junior High-Senior High Combination				25 + 1 per 100 pupils	2.0
Elementary Park Combination				8 + 1 per 100 pupils	0.5
Elementary Junior High-Park Combination				20 + 1 per 100 pupils	1.0
Junior High-Senior High-Park Combination				18 + 1 per 100 pupils	1.0
Junior High-Park Combination				40 + 1 per 100 pupils	2.0
Senior High-Park Combination				35 + 1 per 100 pupils	2.0

*Estimates based on information supplied by Rocky Mountain School Study Council
**Estimates based on U. S. Census Bureau Information

[illegible]

TYPES, NUMBER, AND SIZES OF SPACES IN A CONVENTIONAL ELEMENTARY SCHOOL

Type of Space	Number Needed	Normal class size	Suggested net area in sq. ft.	Minimum Acceptable Size in sq. ft.
Kindergarten	1 per 20 pupils	20	1100-1300	2200
Kindergarten storage, wardrobe, toilets	1 per room		300-350	600
Classrooms	1 per 25 pupils	25	900-1000	27200
Library	1 per 15 or fewer teachers		900-1000	1800
Remedial room	1 per 5 teachers	6-10	400-500	2400
Special classrooms (retarded, gifted)	as needed	12-15	1000-1100	2000
Storage for special classroom	1 per classroom		150-200	300
Auditorium	a. 1 separate unit for schools with more than 21 teachers. Capacity: 50% enrollment b. Combined with cafeterias in schools having 15-21 teachers. c. Multi-purpose room in schools having fewer than 15 teachers.		8 sq. ft. per person	2800
Stage			600-800	600
Physical education	1 full-time use unit per 15 teachers		2400-2800	4800
Storage for physical education	1 per P. E. unit		400-450	800

Type of Space	Number Needed	Normal class size	Suggested net area in sq. ft.	Minimum Acceptable Size in sq. ft.
Cafeteria				
(1) Dining	a. one unit having capacity of one third enrollment		10-12 per diner	2330
	b. Combined with auditorium in schools of 15-21 teachers			
	c. For smaller schools, combined also with physical education and assembly hall			
(2) Kitchen	1 per cafeteria dining		$1\frac{1}{2}$ per meal	1050
(3) Food storage	1 per cafeteria dining		$\frac{1}{2}$ per meal	350
(4) Serving area	2 per dining area		0.8 per diner	190
Principal's office	1 per 21 or fewer teachers		200-250	200
Outer office-clerk	1 per school		250-300	250
additional clerk	1 for schools between 15-21 teachers		100-150	100
Health suite	1 per school		500-550	500
Teachers workroom and lounge	1 per school for 15 or fewer teachers		500-600	1000
Custodial office-workshop	1 per school		500-550	500

Type of Space	Number Needed	Normal class size	Suggested net area in sq. ft.	Minimum Acceptable Size in sq. ft.
Storage of outdoor maintenance equipment and instructional equipment	1 per school		300-350	300
Central storage of instructional materials	1 or 2 per school		0.8-1 per pupil	560
Book storage near classrooms	1 per wing and/or floor		80-100	160
Receiving rooms--incinerator	1 per school		150-200	150
TOTAL MINIMUM ACCEPTABLE ELEMENTARY SCHOOL SIZE (SQ. FT.)				53140

TYPES, NUMBER, AND SIZES OF SPACES IN
CONVENTIONAL SECONDARY SCHOOLS

Types of Space	Suggested Maximum Class Size	Suggested Area of Each Space in sq. ft.	Suggested Area of adjacent Stor. Rm. in sq. ft.	Minimum acceptable Junior High school size in sq. ft.	Minimum acceptable Senior High school size in sq. ft.
SPECIALIZED INSTRUCTIONAL SPACES					
A. ART					
General art	25	1000-1100	100-150	1200	1250
Arts and crafts	25	1100-1300	175-225	1275	1525
B. COMMERCIAL EDUCATION					
Office machines	25	750-850	20-40	770	890
Office practice	25	750-850	20-40	770	890
Typing	35	850-950	20-40	870	990
C. HOMEMAKING					
General	24	1100-1500	50-75	1150	1575
Multi-purpose	4-8	400-500		400	500
Clothing	24	900-1000	50-75	950	1075
Foods	24	1000-1100	50-75	1050	1175
D. MUSIC					
Band-Orchestra	Varies	1200-1400	cabinets	1200	1400
Inst. Storage		250-300		250	300
Chorus	Varies	1200-1400	cabinets	1200	1400
Practice room	1-6	100-125		100	125
Practice room	1-4	75-100		75	100
Practice room	1-2	50-75		50	75
Theory	30	700-900		700	900
Office		150-200		150	200
Music Library	6-10	400-500		400	500

APPENDIX C (continued)

Types of Space	Suggested Maximum Class Size	Suggested Area of Each Space in sq. ft.	Suggested Area of adjacent Stor. Rm. in sq. ft.	Minimum acceptable Junior High school size in sq. ft.	Minimum acceptable Senior High school size in sq. ft.
E. PHYSICAL EDUCATION					
Gymnasium (one teaching station for P.E. only)		3700-4400	300-400	4700	
Gymnasium (two teaching stations)		5600-7000	250-350		7350
Corrective room					
Coach office		The total of these areas			
Toilets		should be approx. 0.7 to		3290	7350
Showers and locker rooms		1.0 X total area of gym.			
Team room					
Std. Girls Gym	40	3000-4000	250-300	3250	3300
Lobby		800-1000		800	1000
F. PHYSICAL SCIENCES					
Biology	25	850-900	150-175	850	1075
Chemistry	25	900-1000	175-200	900	1200
General Science	30	850-900	125-150	850	1050
Physics	25	900-1000	175-200	900	1200
Growing Room		200-300		200	300
Darkroom		60-100		60	100
G. INDUSTRIAL EDUCATION					
I. Industrial Arts (Non-vocational)					
General Shop	20	1500-2000	150-200	1650	2200
Mechanical Drawing	25	800-900		800	900
General metals	20	1700-2000	150-200	1850	2200
General woods	20	1500-1800	150-200	1650	2000

APPENDIX C (continued)

Types of Space	Suggested Maximum Class Size	Suggested Area of Each Space in sq. ft.	Suggested Area of adjacent Stor. Rm. in sq. ft.	Minimum acceptable Junior High school size in sq. ft.	Minimum acceptable Senior High school size in sq. ft.
G. INDUSTRIAL EDUCATION, cont.					
Electrical shop	20	900-1200	100-150	1000	1350
Power Mechanics	20	1600-2200	150-200	1750	2400
Metal shop	20	1600-2200	150-200	1750	2400
Wood shop	20	1400-1600	150-200	1550	1800
Graphic arts	20	1000-1100	150-200	1150	1300
Planning room		400-450		400	450
Finishing room		100-300		100	300
General storage space			250-300	250	300
II. Vocational Education					
Agriculture	18	1200-1600	125-175	1325	1775
Automotive shop	18	2600-3000	150-200	2750	3200
Electrical shop	18	1500-1800	100-125	1600	1925
Mechanical drawing	18	700-800		700	800
Machine shop	18	1500-2000	100-125	1600	2125
Planning room		400-450		400	450
Printing shop	18	1500-2000	60-100	1560	2100
Sheet metal		1800-2000		1800	2000
Woodworking shop	18	1500-2000	160-200	1660	2200
Toilets				600	700
Showers and washroom		140-200		140	200
General storage		750-900		750	900
H. OTHER SPECIALIZED SPACES					
Mathematics lab.	25	850-900	100-125	950	1025
Language arts lab.	30	900-1000	75-100	975	1100
Social studies lab.	30	900-1000	75-100	975	1100

APPENDIX C (continued)

Types of Space	Suggested Maximum Class Size	Suggested Area of Each Space in sq. ft.	Suggested Area of adjacent Stor. Rm. in sq. ft.	Minimum acceptable Junior High school size in sq. ft.	Minimum acceptable Senior High school size in sq. ft.
NON-SPECIALIZED INSTRUCTIONAL SPACES					
Large classrooms	35	850-900	20-40		1000
Medium classrooms	30	750-800	20-40		900
Small classrooms	25	650-700	20-40	1970	790
Core curriculum	30	850-900	75-100		1000
Commercial	30	750-800	20-40		840
SUPPLEMENTARY INSTRUCTIONAL SPACES					
A. AUDITORIUM					
Stage		1800-2200		1800	2200
Audience space		7-8 sq. ft. per pupil		5250	12000
Check room		200-300		200	300
Lobby		1500-2000		1500	2000
Toilets				600	1000
Storage Space		250-300		250	300
B. AUDIO-VISUAL					
Work room - preview room		200-250		200	250
Storage space		250-300		250	300
C. LIBRARY					
Reading room	40-75	1100-1800		1800	3600
Office		125-150		125	150
Book processing room		150-200		150	200
Conference room(s)		150-300		1200	1500
Storage space		175-240		175	240

APPENDIX C (continued)

Types of Space	Suggested Maximum Class Size	Suggested Area of Each Space in sq. ft.	Suggested Area of adjacent Stor. Rm. in sq. ft.	Minimum acceptable Junior High school size in sq. ft.	Minimum acceptable Senior High school size in sq. ft.
C. LIBRARY, continued					
Teaching machine area per 1000 pupil enrollment		600-800		600	1600
D. CAFETERIA					
Kitchen		2 sq. ft. per meal		3000	4000
Dining area		10 sq. ft. per diner		5000	7000
Serving space		0.5-0.8 sq. ft. capacity of dining area		250	560
Storage space		approx. 0.8 sq. ft. per meal		1200	1600
Toilets				600	700
Teachers dining area		12 sq. ft. per diner		480	960
E. REMEDIAL INSTRUCTIONAL SPACES					
Reading		400-500		400	500
Speech		400-500		400	500
General		400-500		400	500
F. STUDENT ACTIVITY					
Activity room		450-600		450	600
Storage space		80-100		80	100
G. STUDY HALL					
Study room		15-20 sq. ft. per pupil		3750	7000

APPENDIX C (continued)

Types of Space	Suggested Maximum Class Size	Suggested Area of Each Space in sq. ft.	Suggested Area of adjacent Stor. Rm. in sq. ft.	Minimum acceptable Junior High school size in sq. ft.	Minimum acceptable Senior High school size in sq. ft.
ADMINISTRATIVE AND RELATED AREAS					
A. ADMINISTRATION					
Principal		200-250		200	250
Vice Principal		150-200		150	200
Assistant Principal(s)		150-200		300	600
Clerk-waiting area		300-350		500	650
Storage (office supplies)		75-100		75	100
Vault		50-75		50	75
Toilet		40-50		40	50
Conference rooms		250-300		250	300
B. GUIDANCE					
Guidance counseling offices		120-150		600	840
Guidance director's office		150-200		150	200
Guidance library/ workroom		200-250		200	250
Small group guidance space		125-150		125	150
Individual testing space		40-50		80	100
Storage space		30-40		30	40
C. HEALTH					
Office (nurse)		150-175		150	175
Exam room		275-300		275	300
Waiting space		100-150		100	150

APPENDIX C (continued)

Types of Space	Suggested Maximum Class Size	Suggested Area of Each Space in sq. ft.	Suggested Area of adjacent Stor. Rm. in sq. ft.	Minimum acceptable Junior High school size in sq. ft.	Minimum acceptable Senior High school size in sq. ft.
C. HEALTH, continued					
Rest rooms		100-125		100	250
Toilets		30-40		30	80
D. TEACHERS' ROOMS					
Common lounge		700-800		700	1400
Toilets		250-300		500	600
Work rooms		300-350		300	350
Storage		30-40		30	40
Faculty library		450-500		450	500
Faculty office		100-120		1300	1920
SERVICE AREAS					
A. CUSTODIAN					
Office		100-150		100	150
Storage		50-75		50	75
Toilet and shower		100-125		100	125
Workshop		250-300		250	300
Storage of custodial supplies		150-200		150	200
Service closets		20-25		80	150
Receiving room		150-200		150	200
Storage of outdoor equip.		100-150		100	150

APPENDIX C (continued)

Types of Space	Suggested Maximum Class Size	Suggested Area of Each Space in sq. ft.	Suggested Area of adjacent Stor. Rm. in sq. ft.	Minimum acceptable Junior High school size in sq. ft.	Minimum acceptable Senior High school size in sq. ft.
B. OTHER SERVICE SPACES					
Book storage at various locations		40-50		160	200
General storage of instructional supplies		½ sq. ft. per pupil in school		500	750

TOTAL MINIMUM ACCEPTABLE JUNIOR HIGH SCHOOL SIZE (SQ. FT.)	100000
TOTAL MINIMUM ACCEPTABLE SENIOR HIGH SCHOOL SIZE (SQ. FT.)	148795

AN INVESTIGATION INTO THE USE OF CONCEPTUAL LINEAR PROGRAMMING AND CAPITAL BUDGETING IN SCHOOL PLANNING

by

CLAUDE A. KEITHLEY

B. Architecture, Kansas State University, 1965

AN ABSTRACT OF
A MASTER'S REPORT

submitted in partial fulfillment of the

requirements for the degree

MASTER OF REGIONAL AND COMMUNITY PLANNING

Department of Community and Regional Planning
College of Architecture and Design

KANSAS STATE UNIVERSITY
Manhattan, Kansas

1973

This is a report of a model developed as a result of a planning project while the author was employed in the Urban Planning Department, Howard, Needles, Tammen & Bergendoff. The author had the responsibility of allocating schools to the various neighborhoods delineated by a neighborhood analysis of Lake Charles, Louisiana in 1966. At that time relatively little information was available concerning the methodology of making such allocations. However, the time frame under which the final plan was prepared necessitated a valid allocation with minimal methodology.

The model presented in this report is a result of research initiated by the author at the completion of the Lake Charles plan and represents an attempt to utilize the concepts of linear programming with financial constraints imposed by the capital budgeting process. The model is considered to be an experimental design that represents a "real world" process. It is presented in matrix form using the data developed earlier for the Lake Charles Study Area.

A review of the available literature on models considered to be of use in the planning profession is included in the report. The advent of mathematical analysis has been received with mixed emotions in the field of planning. There is, however, a general recognition that such an analysis can be of use in the solution of certain types of problems. Models, in general, do not relieve the planner of the many judgements necessary to the implementation of a comprehensive development plan. The models are intended to assist the planner in assessing the rationale of his decision processes. Many factors come into play in every decision, and any process which will assist the planner in his assessment can be considered worthwhile. The planner is then able to spend his judgemental time on other "human" factors which do not lend themselves to mathematical analysis.

In conclusion, the author assessed the utility of the model for planners, school administrators and budgeting personnel in terms of the completed plan. The planner obtains the utility of being able to justify his judgements on school locations within the municipality's financial framework. The utility to other persons, directly or indirectly related to school planning and budgeting lies in the knowledge that the completed plan can be implemented within the financial resources of the municipality. The results of the model testing did not indicate acceptance of the stated hypothesis in that additional factors were deemed needed to link school allocations and financial constraints. The technique of linear programming, however appears to be applicable in models of this type.