ANALYTICAL MAPS FOR SCHOOL LOCATIONAL PLANNING

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INTRODUCTION

School locational planning, expressed perhaps in more contemporary terms, is viewed as the planning activity that attempts to answer such questions as:

- Where to locate individual school attendance zone boundaries?
- How should students be allocated to schools to satisfy desegregation requirements?
- Which schools should be closed when schools are underutilized?
- How should the city grow relative to existing school facilities?
- Where should additional classrooms (protables, in particular) be built?
- Where should new schools be built?
- How many buses are needed and how should they be routed?

These questions consume much time and are seldom done with the most efficient tools available. This paper illustrates how maps of linear programming solutions, which are referred to as analytical maps, can aid in providing meaningful and expedient answers to many of the questions posed above.1/ Examples of such maps are presented here based upon data collected in 1972 for a case study of Topeka, Kansas, a city with a population of about 150,000. The emphasis of the paper is on the presentation of the results of a linear programming application for school locational planning through the use of maps rather than on the formulation of models.

THE MODELS

Two student-allocation models based on linear programming were used in the Topeka case study. These two models minimize total student travel distance to schools. One model satisfies this objective when students are allocated to neighborhood schools; the other is a model for desegregation. That is, constraining equations restrict student assignments to schools by race. Both models state that all students

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must be assigned to schools while school seating capacity cannot be exceeded in the process. A summary of the model objectives and the restrictions on the objective functions is provided in the table below.

Two Types of Student-Allocation Models

	NEIGHBORHOOD	DESEGREGATION
OBJECTIVE:	Minimize Total Student Travel to Schools	Minimize Total Student Travel to Schools
WHEN:	All Students Must Be Assigned	All Students Must Be Assigned
	School Seating Capacity Cannot Be Exceeded	School Seating Capacity Cannot Be Exceeded
		Student Assignments By Race Cannot Exceed Some Fraction of School Seating Capacity
		Student Assignments By Race Must Satisfy Some Minimum Fraction of School Seating Capacity

DATA REQUIREMENTS

The models specify three principal data requirements:

- Collection of data that permits mapping the spatial distribution of student residence by grade level.
- Acquisition of data that characterizes the inconvenience of travel between student residence and schools, such as travel distance, vehicle operating costs, or travel time.
- Acquisition of information that defines the effective seating capacities of schools.

In the case of the desegration type student-allocation model, the seating capacities of schools and the spatial distribution of student residence have to be known by race as well as by grade level.

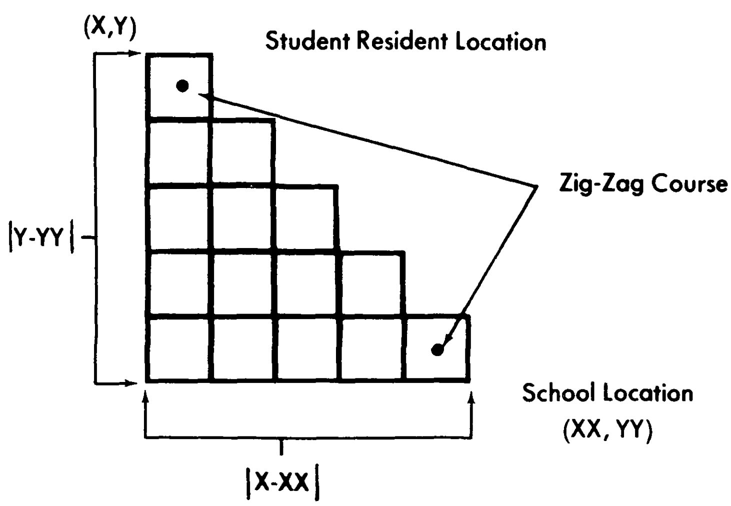
School administrations typically record the location of student homes by street address. Because of this, a capability for matching students to a given geographical location must be obtained in order to use the student-allocation models. Where the U.S. Bureau of the Census DIME files have been created, a basic mapping tool is available from which student address matching can proceed for determining the exact number of students by grade level living on a given block.2/ In the case of Topeka, address matching is accomplished manually. This manual operation in 1972 involved aggregating the exact number of students by grade level for some 24,000 students into blocks which were subsequently coded for computer retrieval.

The distance students walk to schools, as approximated by the computer calculation of the horizontal plus vertical differences between two sets of x,y coordinates (referred to as rectilinear distance in (Figure 1), was used rather than vehicle operating cost or travel time as the measure of student travel to schools. The use of the other two measures (vehicle operating costs and travel time) did not seem particularly appropriate at the time of the study since Topeka was then transporting only some 200 to 300 special education students of the 24,000 or so students enrolled in the school district.

Information defining the effective school capacities was also obtained from the school administration. The map of Figure 2 shows the approximate size and date of construction for the twelve junior high schools that were in use in 1972 and upon which the case study focused.

Figure 1

RECTILINEAR DISTANCE



Formula for Calculating Rectilinear Distance (D):

$$D = |x-xx| + |y-yy|,$$

Where

(x,y) is the centroid location of the student resident location

(xx,yy) is the centroid location of the school site.

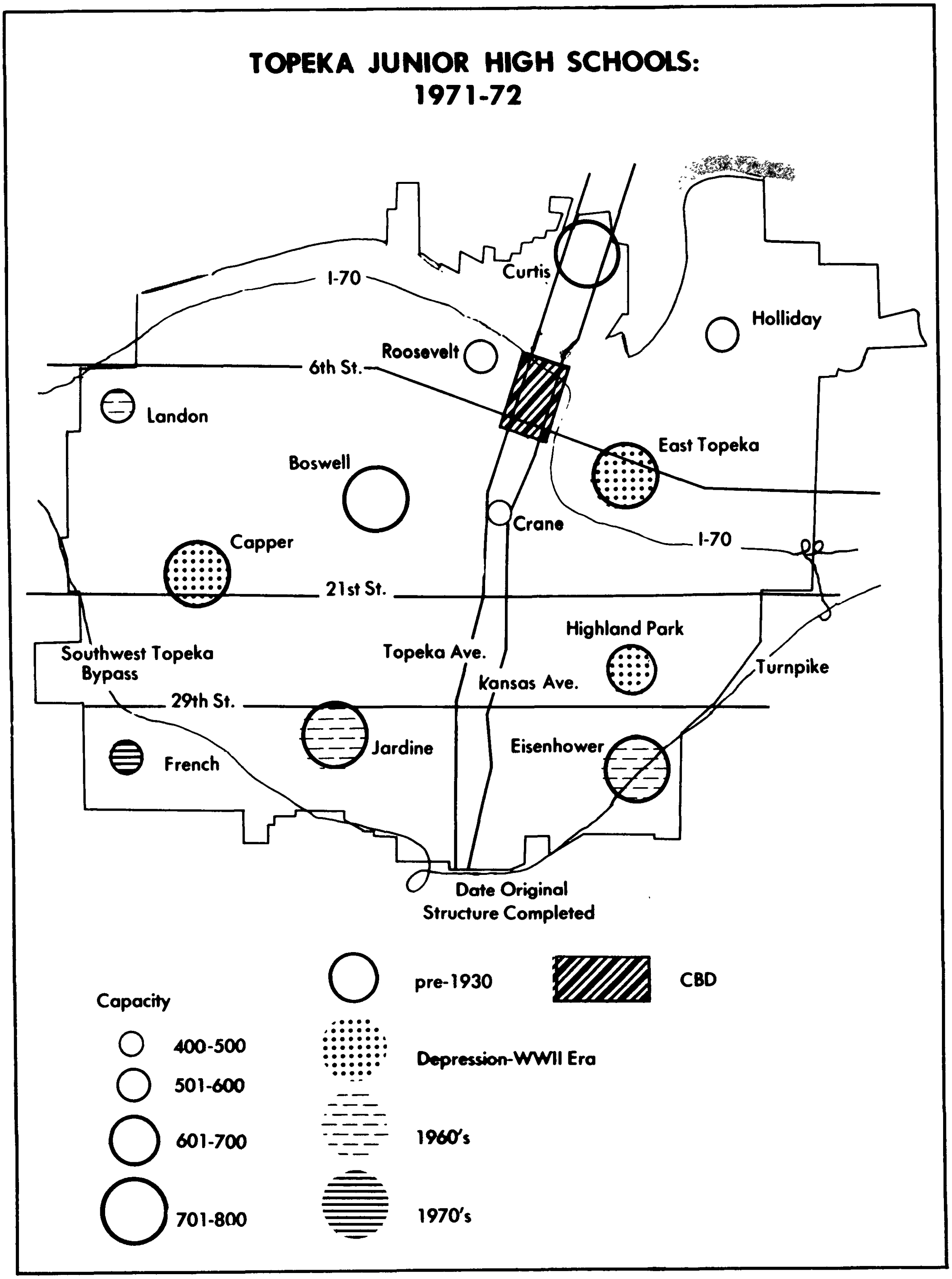
RESULTS

A few of the results based on the Topeka case study are now presented using analytical maps to address the questions: Where to locate individual school attendance zone boundaries? How should students be allocated to schools to satisfy desegregation requirements? Which schools should be closed? and How should the city grow relative to existing school facilities?

DRAWING NEIGHBORHOOD SCHOOL ATTENDANCE ZONE BOUNDARIES

In those school districts where students are assigned to their neighborhood schools, school attendance zone boundaries must be drawn come the start of each school year. One of the principal concerns of the school planner is drawing the boundaries such that the distance children live from school is not so far as to be an unreasonable distance to travel each day. Ideally, student travel should be minimized.

Figure 2


TOPEKA JUNIOR HIGH SCHOOLS:
1971-72
I-70
Curtis
Holliday
Roosevelt
6th St.
Landon
East Topeka
Boswell
Crane
I-70
Capper
21st St.
Highland Park
Southwest Topeka
Bypass
Topeka Ave.
Kansas Ave.
Turnpike
29th St.
Jardine
Eisenhower
French
Date Original
Structure Completed
pre-1930
CBD
Capacity
400-500
501-600
601-700
701-800
Depression-WWII Era
1960's
1970's

The map of Figure 3 shows the boundaries of neighborhood school zones based on minimizing student travel distance as compared to the boundaries drawn by the school administration for the 12 Topeka junior high schools. The shaded area reflects graphically the differences between the optimal and the actual attendance zones or the cost of deviating from an optimal pattern. In particular, these disparities in attendance zone assignments reflect a basis toward assigning students to the newer schools rather than to the closest schools. French and Landon are the two newest junior high schools in Topeka (refer to Figure 2) and neither is centrally located relative to the geographical distribution of students. This is supported by the fact that the model only assigned students to these schools in the amounts of 48.4 and 32.1 per cent of their capacities, respectively. School officials might rightfully argue that these newer schools would be operating at unrealistically low capacities if the model results were implemented. If such were the case, an additional constraint could be added to the model to assure that a minimum, acceptable number of students were assigned.

DESEGREGATING SCHOOLS

Court ordered school desegregation is a perplexing problem for any school administration. One of their principal concerns is limiting the travel between where students live and their assigned schools while still satisfying Department of Health, Education and Welfare requirements. The map of Figure 4 shows an example of a graphical output from a desegregation-type student-allocation model. It is thought that such a map could aid school officials when attempting to develop a school desegregation plan.

In this particular case, the map depicts Black student assignments to each junior high school when the enrollment in each school must be at least 6.5% Black. This percentage is one-half of the overall proportion of Black student enrollments in Topeka junior highs; their proportion of total enrollment is 13 percent. A similar kind of map could be constructed based on the model results for White students.

CLOSING SCHOOLS DUE TO DECLINING ENROLLMENTS

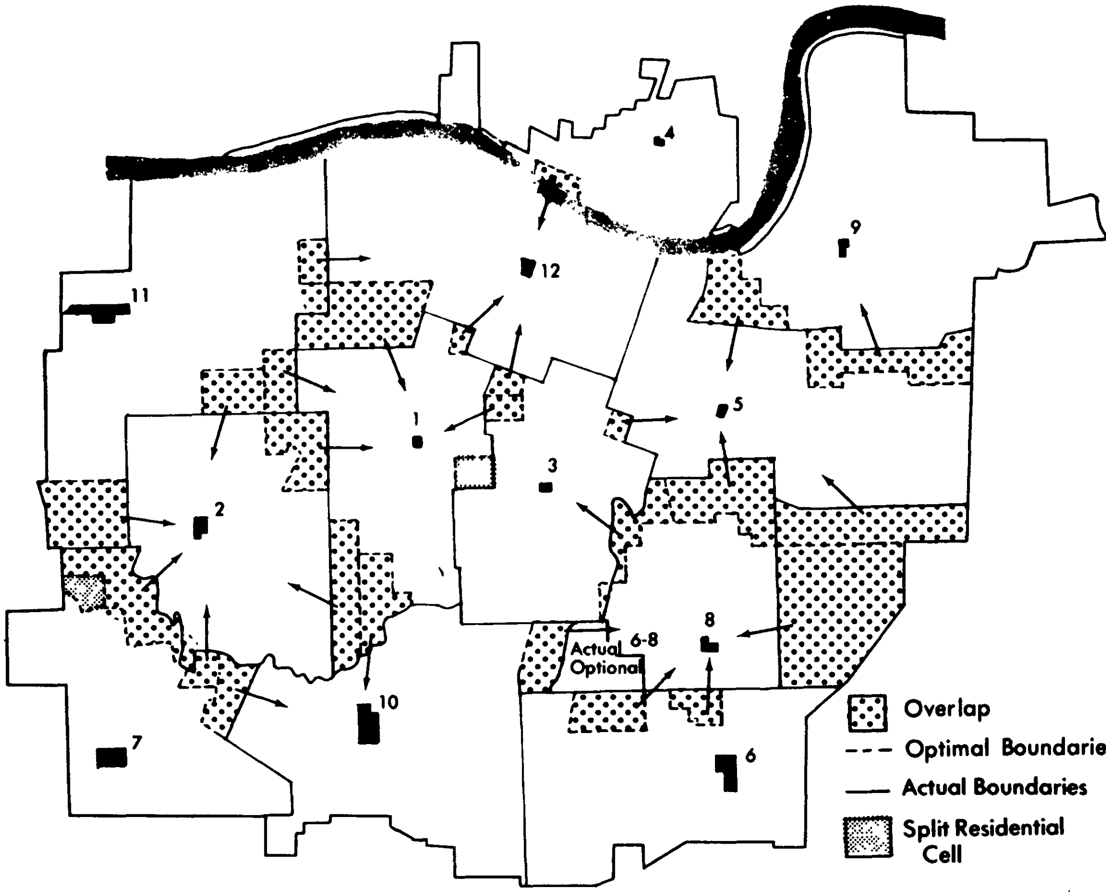
A pervasive problem throughout much of urban America today is that of having to close school facilities due to declining school enrollments. Even some relatively modern schools that were built just after World War II, particularly in the new suburbs of that time, are now being closed. Ironically, these same schools ten to twenty years ago were full, and in many instances, were overflowing just as shcools in new suburbs are today. Also, and as a consequence, smaller and older schools built 35 to 40 years ago are being closed so that their students can be transferred to these more modern schools that are now underutilized. Such is the case today in Topeka.

The Crane and Curtis junior high schools (refer to Figure 2), which were built in the 1920's have been closed and their students have as a result been transferred to nearby schools -- those with relatively modern facilities and declining enrollments in their immediate attendance areas. This was accomplished not without resistance from parents living in the immediate vicinity of the schools closed. A quotation provided by a Topeka citizen is pertinent:

> I'm looking very hard from a property owner's standpoint as well as a parent's standpoint. If you tear out all my schools, it's going to drop my property values. I moved into this area because of the schools. 3/

Figure 3

OPTIMAL VS. ACTUAL JUNIOR HIGH SCHOOL ATTENDANCE ZONES



Sch ID	Sch Name	Cap	No. of Students Assigned	% of Sch Cap
1	Boswell	736	736	100.0
2	Capper	732	732	100.0
3	Crane	456	421	92.3
4	Curtis	346	228	57.6
5	East Topeka	800	567	70.9
6	Eisenhower	750	507	67.6
7	French	570	276	48.4
8	Highland Park	612	492	80.4
9	Holliday	524	407	76.2
10	Jardine	750	711	94.8
11	Landon	533	218	37.1
12	Roosevelt	570	425	74.6

Figure 4

BLACK STUDENT ASSIGNMENTS: A TWO-RACE STUDENT-ALLOCATION MODEL OUTPUT

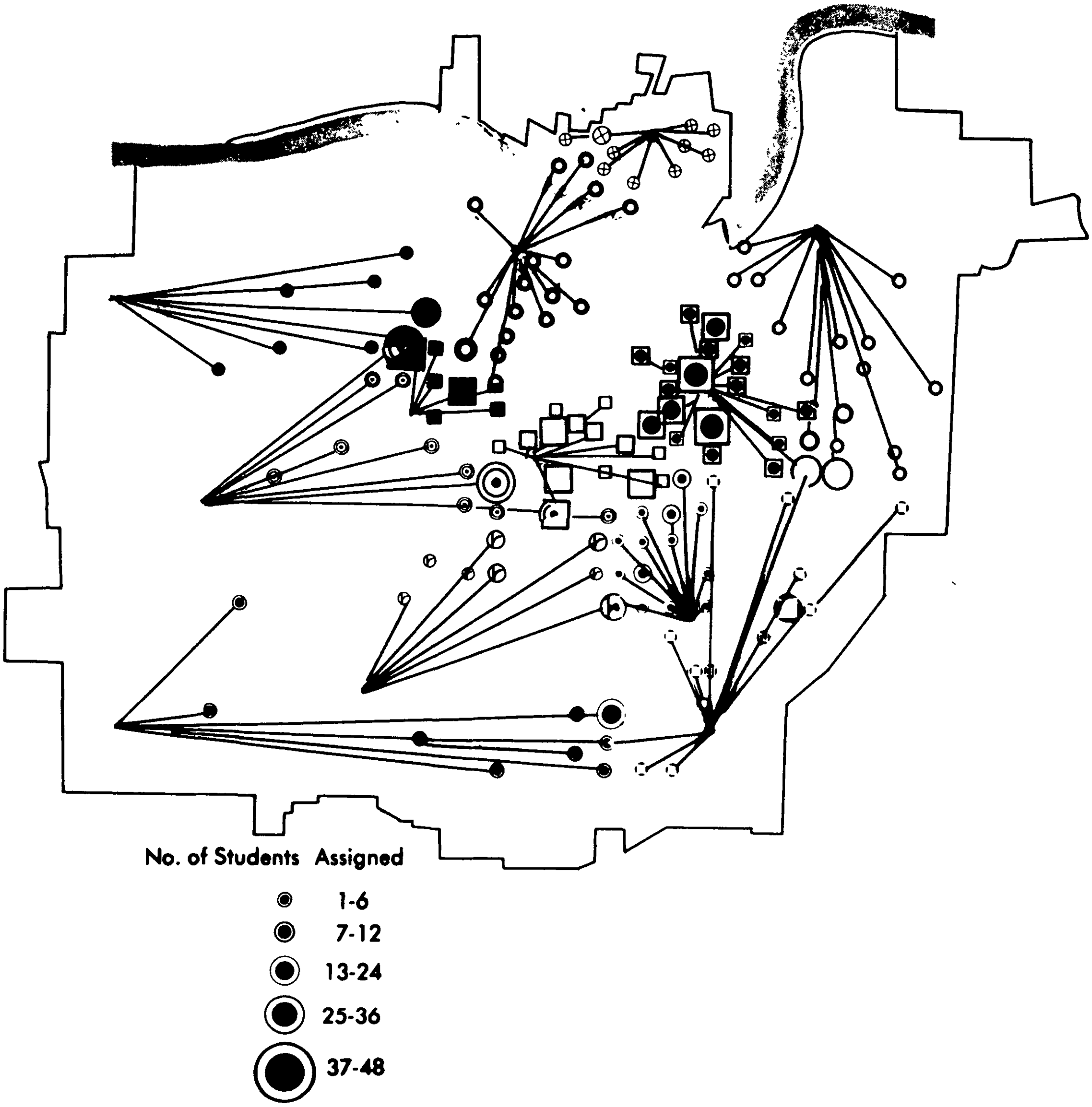
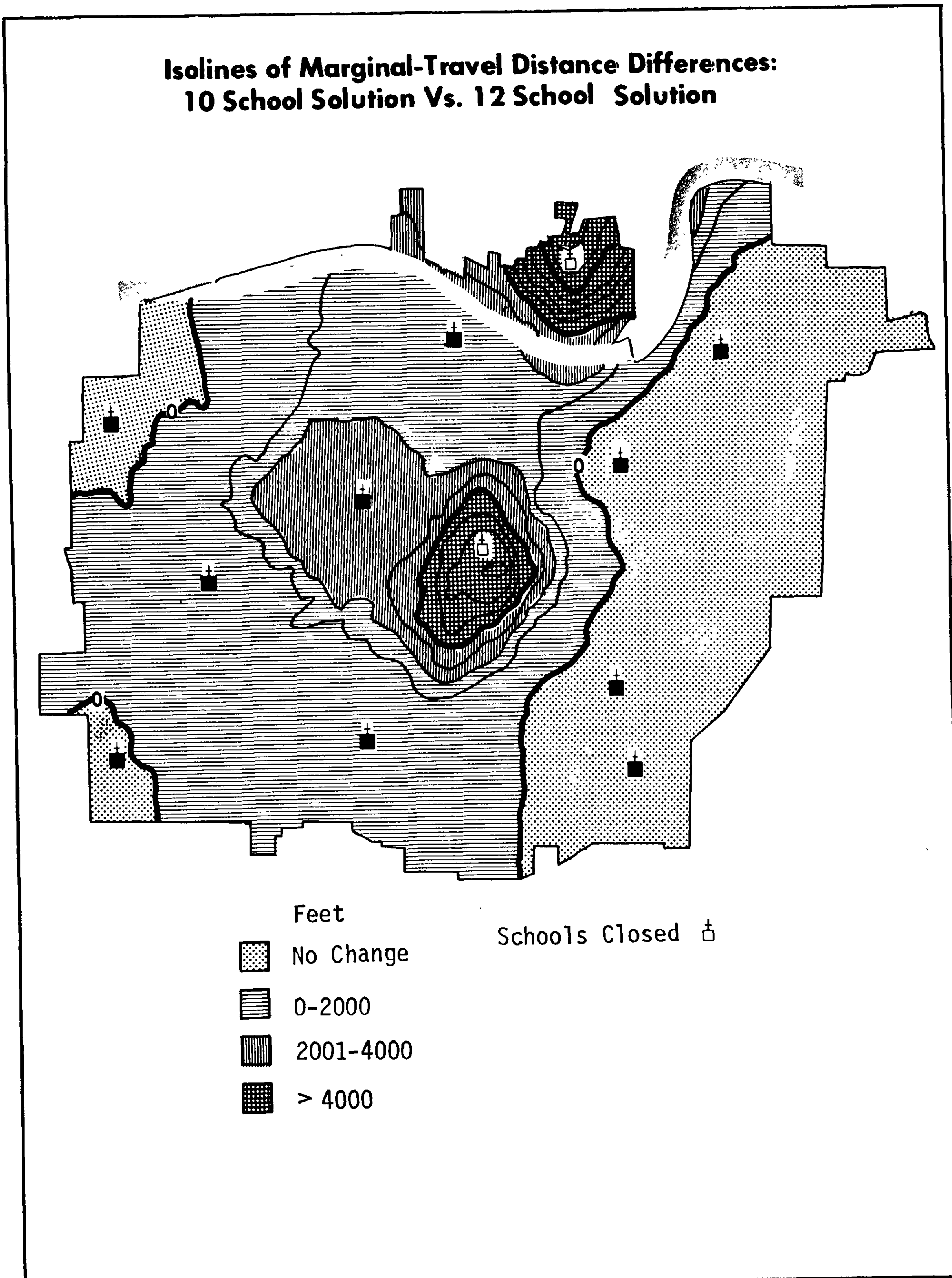


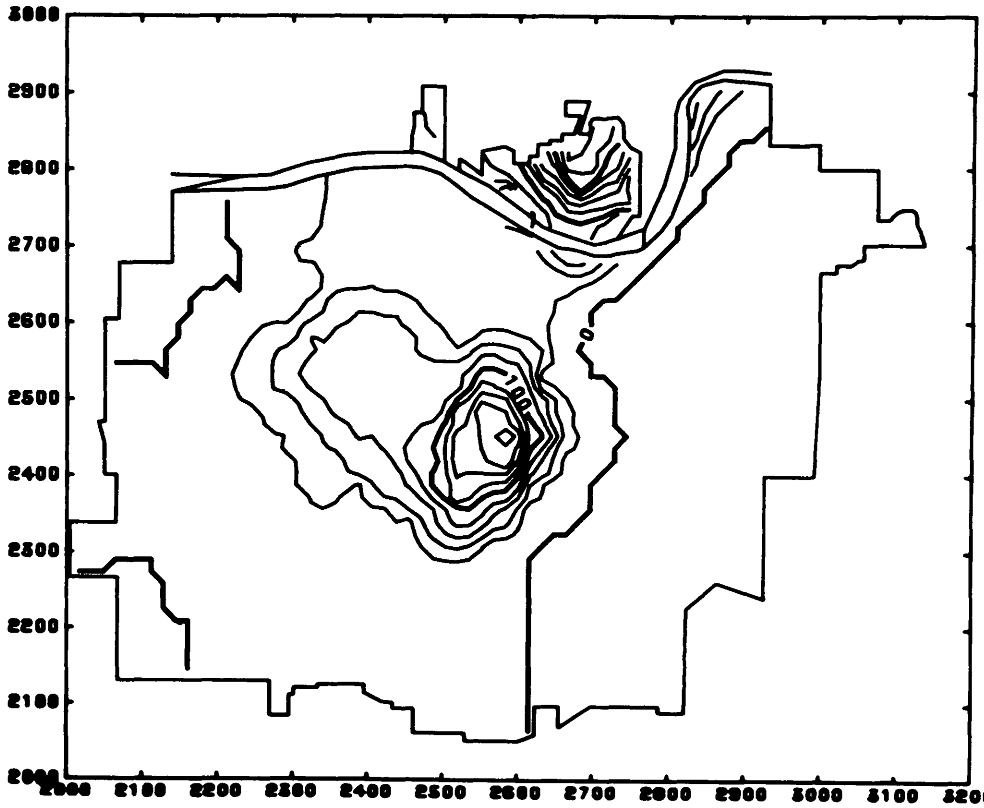
Figure 5


Isolines of Marginal-Travel Distance Differences:
10 School Solution Vs. 12 School Solution
Feet
No Change
0-2000
2001-4000
> 4000
Schools Closed

Maps based on student-allocation model results can show the impact of closing schools on student travel; and, subsequently, provide a measure of school closure impact on residential property value. The isopleth map of Figure 5, for instance, shows the areas most affected when Crane and Curtis junior highs are closed. This map was constructed from the computer-produced isoline map 4/ of Figure 6. Note that a much larger area throughout West Topeka is "devalued" in relation to junior high school locations than in East Topeka as a result of the school closures. In a similar way, the spatial impact of closing other schools could be analyzed or an evaluation could be made to determine which school closure -- Curtis or Crane -- had the least spatial impact.

Figure 6

SURFACE II ISOLINE MAP

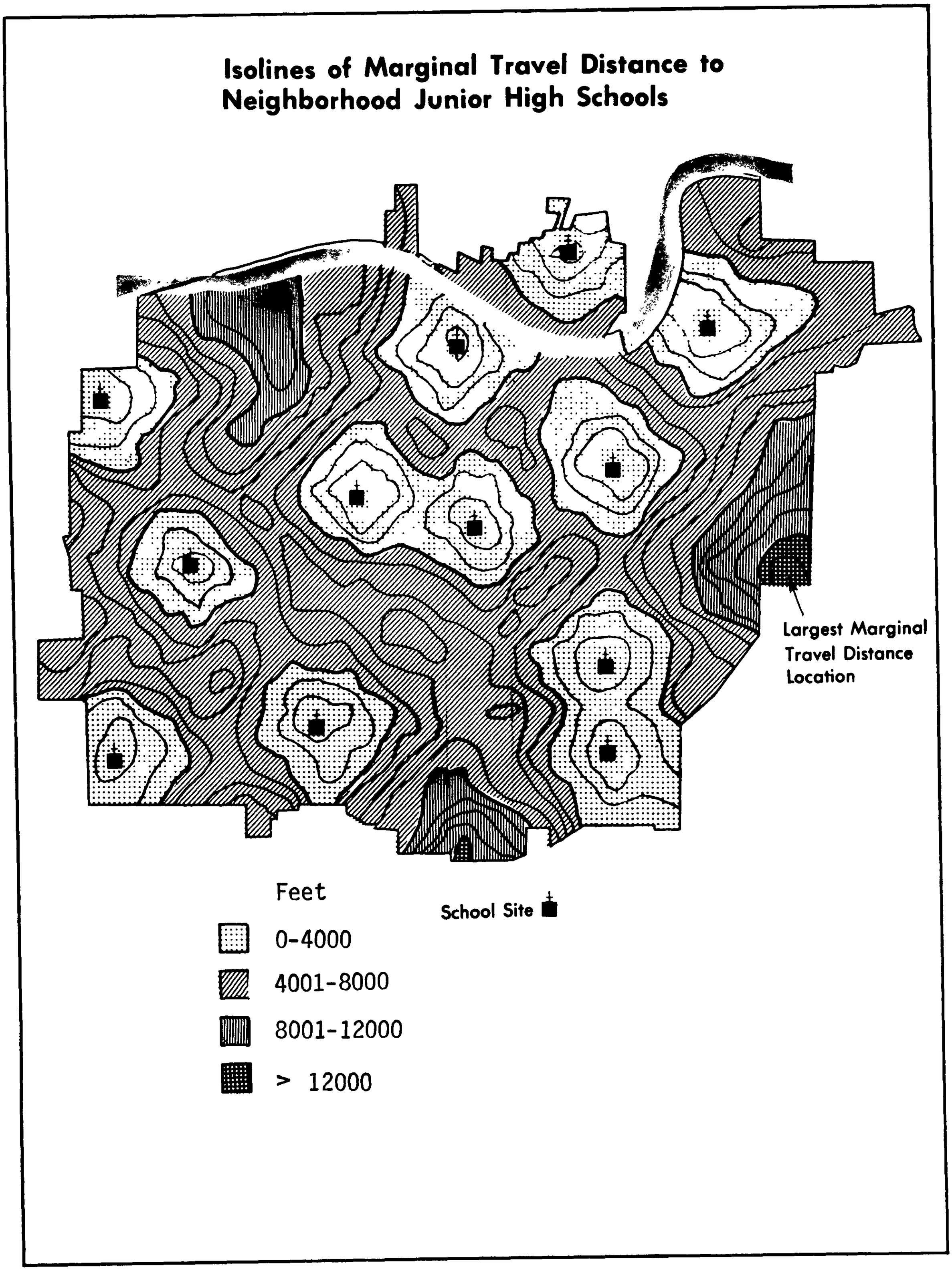


DETERMINING WHERE TO ZONE RESIDENTIAL DEVELOPMENT RELATIVE TO SCHOOL FACILITIES

The concern expressed in the quotation by the citizen of Topeka toward closing schools should make the point that schools have an important bearing on where people decide to live. It, therefore, is only logical that city planners should seriously consider the importance of school locations in their residential zoning plans. When doing so it is thought that maps based on student-allocation model results should be of some help to the city planner.

The isopleth map of Figure 7, for instance, shows the best and worst locations for residential development relative to school locations. In the worst situation,

Figure 7


Isolines of Marginal Travel Distance to
Neighborhood Junior High Schools
Largest Marginal
Travel Distance
Location
Feet
School Site
0-4000
4001-8000
8001-12000
> 12000

housing development per every student added to the school district would result in adding 8,000 feet or more student travel for the school system as a whole. Residential development in the best locations would result, on the other hand, in increasing total student travel from zero to 4,000 feet per student increase due to building more homes. Zero travel in effect would result when homes are built immediately adjacent to school sites.

SUMMARY AND CONCLUSIONS

The emphasis in this paper has been on the use of analytical maps for school location planning. In particular, the paper has illustrated how maps based on linear programming solutions for minimizing student travel to schools can be used to help resolve such issues as closing schools, desegregating schools, and determining the location of neighborhood school zone boundaries. In some instances, it has been shown how these types of maps might be useful to city planners as aids for zoning residential developments.

In concluding, two lessons have been learned in the process of producing the analytical maps exhibited here.

First, efficient, expedient mapping techniques, that only automation in cartography can provide, must be employed for determining where students live relative to school locations. That is, without such a mapping capability, the analytical process or application of a mathematical or statistical model cannot be effective, especially, if one is concerned about saving money and time in the process of producing maps. This is particularly true if the application is going to be made in a very large city, one much larger than Topeka, Kansas. I was fortunate in my Topeka study in that the school district had already performed a basic mapping task for me: matching student addresses in order to determine the exact number of students by grade level living on any given block. As noted earlier, the school administration is conducting this work manually. But, this is unusual and they deserve much credit since they became concerned about their data base for mapping applications sometime before the DIME innovation. What is particularly lacking in their operation now is further application of automation in cartography. The software and hardware for producing plots of where students live by grade level is one automatic mapping application that would serve them particularly well. It is unfortunate that this additional extension to their capability has not been made, especially, given the effort they have gone to in developing their data base.

Secondly, I would like to emphasize that the maps exhibited in this paper took time to construct. The most time-consuming chore involved coding and key punching the output or results provided by linear programming. A simple routine is needed in the software that will output the results onto tape or cards in a form compatible with a mapping system. My point is that expedient ways of getting the model results onto maps must also be given a great deal of consideration before applying such an analytical tool as linear programming. Most library programs for statistics and math do not provide options for outputting the results to a plot tape or cards which then can be used as input to mapping software. In most instances now, one merely obtains from the computer reams upon reams of line-printer output, containing the results you want, but results that are meaningless until displayed on a map.

REFERENCES

1. Linear programming has been used before as an aid to assigning students to schools: Yeates, Maurice, "Hinterland Delimitation: A Distance Minimizing Approach," Professional Geographer, Volume 15, Number 6, November 1963, pp. 7-10; Heckman, Leila B. and Taylor, Howard M., "School Rezoning to Achieve Racial Balance: A Linear Programming Approach Journal Socio-Economic Planning Science, Volume 3, 1969, pp. 127-33; Maxfield, Donald W., "Spatial Planning of School Districts Annals of the Association of American Geographers, Volume 62, Number 4, December 1972, pp. 582-90.

2. Schofield, Jack, "Pragmatic Use of the DIME File," Geographic Base (DIME) File System: A Forward Look, Proceedings of Conference co-sponsored by the Massachusetts Bureau of Transportation Planning and Development, the Transportation Systems Center, and the Urban Systems Laboratory of M.I.T., Boston, Massachusetts, 16 and 17 April 1974, pp. 33-37.

3. "Opposition is Voiced to School Board Plan," The Topeka State Journal, May 1, 1974, p.1.

4. The SURFACE II program was used to construct this isoline map. For further details, see: Sampson, Robert J., User's Manual for the SURFACE II Graphics System, Geologic Research Section, Kansas Geologic Survey, Lawrence, Kansas, 1973.