DOCUMENT RESUME

ED 137 035 RC 009 813

AUTHOR Sadler, Ronald A.; Ching, C. T. K.
TITLE Optimal School Location in Rural Nevada. Nevada Agricultural Experiment Station Bulletin, B-35, February 1975.
INSTITUTION Nevada Univ., Reno. Agricultural Experiment Station.
SPONS AGENCY Department of Agriculture, Washington, D.C.
PUB DATE Feb 75
NOTE 18p.; Some parts may be marginally legible due to small print type of original

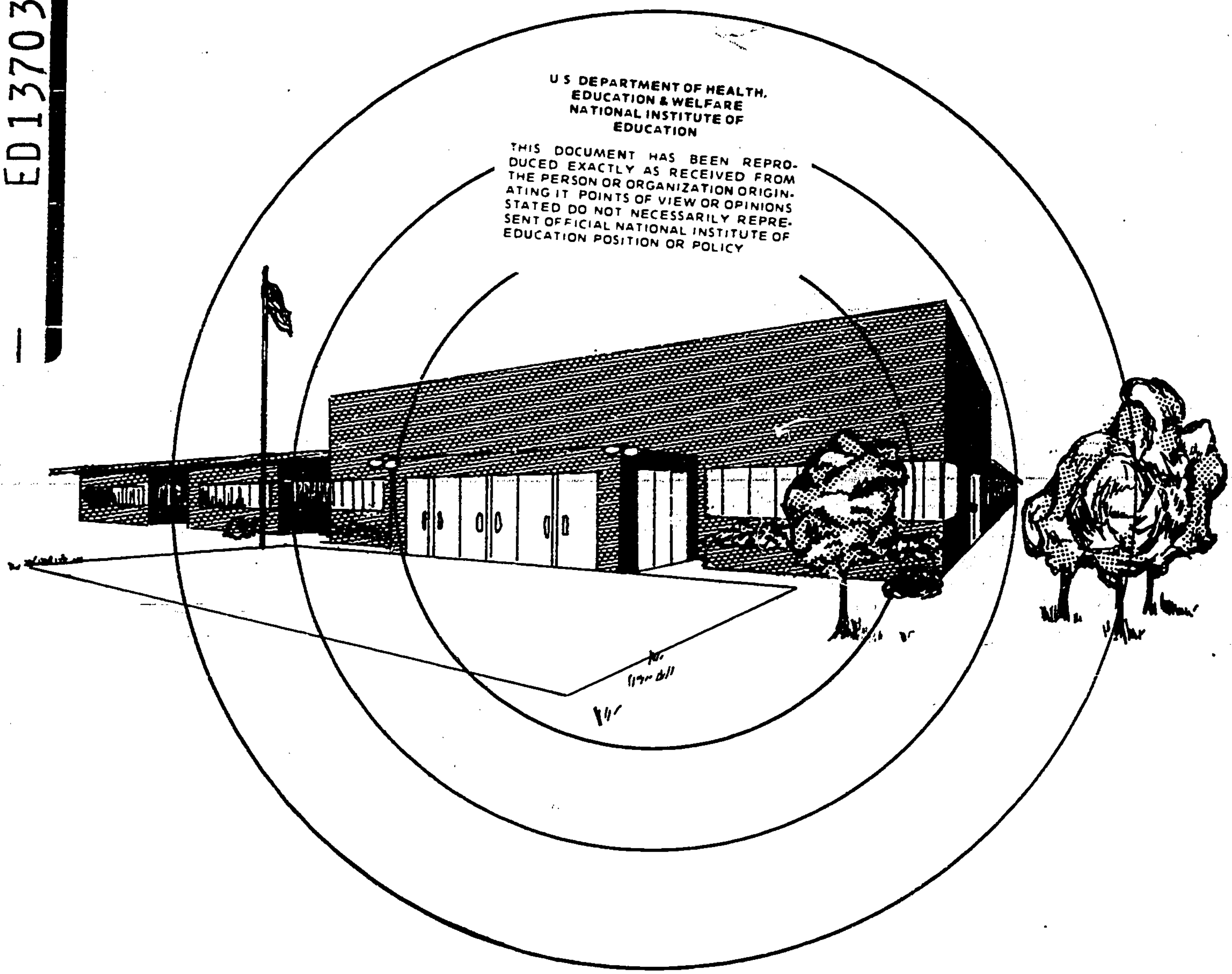
EDRS PRICE MF-$0.83 HC-$1.67 Plus Postage.
DESCRIPTORS *Bus Transportation; *Cost Effectiveness; Curriculum; Distance; Educational Quality; *Models; Organization; *Rural Areas; School Districts; *School Location; School Size; *Student Teacher Ratio; Transportation
IDENTIFIERS *Nevada

ABSTRACT

In order to investigate the interaction of cost, quality, and efficiency in the provision of educational services in rural Nevada, synthetic cost functions were developed using a linear programming transportation model to identify optimal school district organization. Optimal school district organization was defined for specific levels of educational quality (breadth of curriculum), student-teacher ratios, cost of transportation, and maximum bussing distances for students in the region. Alternative district organizations were considered by varying these parameters and observing sensitivity of optimal solutions. It was found that by increasing the student-teacher ratio from 20:1 to 30:1, operating costs would be reduced by 17% and that transportation costs would have to increase by over 200% before they became a critical factor in the definition of optimal district organization. Changing the assumed bussing mileage limits did have a significant effect on the location and size of schools in the region. Assuming that no student could be bussed more than 50 miles (one way) resulted in three schools in solution. Assuming a 75-100 mile limit resulted in only two schools in solution. The versatility of the linear programming transportation model was demonstrated in terms of its ability to provide cost comparisons for changes in program sizes, student-teacher ratios, permitted school locations patterns, bussing costs, and changes in permitted bussing distances by students. (Author/JC)

FEBRUARY 1975 B 35

Optimal School Location in Rural Nevada



RONALD A. SADLER
C. T. K. CHING

AGRICULTURAL EXPERIMENT STATION
MAX C. FLEISCHMANN COLLEGE OF AGRICULTURE UNIVERSITY OF NEVADA RENO
DALE W. BOHMONT, DEAN AND DIRECTOR

ABSTRACT

This study sought to investigate the interaction of cost, quality, and efficiency in the provision of educational services in rural areas. Synthetic cost functions were developed and a linear programming transportation model was used to identify optimal school district organization. The model was applied to a rural region in Nevada.

Optimal school district organization was defined for specific levels of educational quality (breadth of curriculum), student-teacher ratios, cost of transportation, and maximum bussing distances for students in the region. Alternative district organizations were considered by varying these parameters and observing sensitivity of optimal solutions. It was found that by increasing the student-teacher ratio from 20:1 to 30:1, operating costs would be reduced by 17 percent. Further, it was found that transportation costs would have to increase by over 200 percent before they became a critical factor in the definition of optimal district organization. In contrast, changing the assumed bussing mileage limits did have a significant effect on the location and size of schools in the region. Assuming that no student could be bussed more than 50 miles (one way) resulted in three schools in solution. Assuming a 75- or 100-mile limit resulted in only two schools in solution.

Generally, the study illustrated the versatility of the linear programming transportation model in its ability to provide cost comparisons for changes in program sizes, student-teacher ratios, permitted school locations patterns, bussing costs, and changes in permitted bussing distances by students.

OPTIMAL SCHOOL LOCATION IN RURAL NEVADA

Ronald A. Sadler and C.T.K. Ching[1]

I. Introduction

In this study, educational problems are viewed as revolving around two central considerations: (1) educational costs and (2) educational quality. Education costs require a little elaboration. Education is not different than other goods and services in that its cost is soaring. For example, in Nevada trend analysis of State Department of Education records [15] indicate that education costs have been increasing at about 13.5 percent per year. With such increases in costs, the problem facing school administrators and educational planners is one of providing an acceptable "quality" of education at minimum cost.

A. Educational Quality

While the issue underlying educational costs are straightforward, those underlying educational quality are less so. There are two generally accepted measures of educational quality. The first involves investigation of the inputs going into an educational system such as course diversity, school facilities, student-teacher ratios, and the quality of teachers and administrators. These input quality measures have been appropriately criticized since there are instances where the highest quality of inputs will not result in a high quality of educational output [13]. Accordingly, some researchers and educators have turned to another measure of quality–standardized achievement tests [4,14, 20]. This measure is directly related to how well a particular student has been trained in the educational system. The varying backgrounds of students (e.g., influence of family and peers) are essentially held constant, since a student is assessed only relative to how he performed in the beginning of the period or academic year. Opponents of this quality measure argue that achievement tests are oriented toward white, middle class students, and as such reflect a socio-economic bias.

The point to be made regarding educational quality, however, is that there is no generally accepted measure of quality. For this study, an input quality measure, course diversity, is used as a measure of quality [13,19]. While we clearly recognize this measure's limitations, it appears most appropriate for planning since educational administrators and planners have direct control over this quality measure.

B. Economic Efficiency

As noted, one approach to achieving economic efficiency in schools would be to attain some given standard of educational quality in a least-cost fashion. In this study, a linear programming (LP) model is used to solve problems of this type [8]. More specifically, a linear programming transportation model is used to indicate the number of schools, sizes, and locations which minimize the combined cost of transportation and operation while holding quality (course diversity) constant.

C. Objectives

This report seeks to provide insights on the following questions pertaining to Nevada school districts.

1. What are the major cost components of educational programs in rural Nevada high schools?

2. How do the concepts of cost, quality, and efficiency interact in the development of educational programs in Nevada high schools?

3. Can rural Nevada school districts be reorganized to provide a more efficient (the same or better quality at lower cost) high school program?

[1]Graduate Research Assistant and Associate Professor, Division of Agricultural and Resource Economics, University of Nevada Reno.

p. 2 blank

4. Do linear programming techniques provide a practical approach to the analysis of spatial organization and operating efficiency in Nevada school districts?

II. Region Studied

A region consisting of more than one school district was selected because several rural school districts in Nevada have only one or two high schools.[2] More specifically, two criteria were followed in selecting the study region. First, the districts should be contiguous; and, second, the selected districts should be located in a rural area. Based on these, the region consisting of Eureka, Lincoln, and White Pine school districts in east central Nevada were selected (Figs. 1-3). This region contains five high schools and provides a sufficiently rigorous test of the LP model while not being overly complex for analysis. Existing high schools are in Ely, Lund, Panaca, Alamo, and Eureka. Respective 1973-1974 enrollments were 780, 40, 165, 51, and 50, for a total senior high school (grades 9-12) enrollment of 1,086 in these districts.[3]

III. Cost of Providing Education

Educational cost is viewed as containing four major components:

1. Instruction costs: teacher salaries, principal salaries, counselor salaries, clerical salaries, and teaching supplies.
2. Maintenance and plant operation costs: salaries for custodians and maintenance personnel, janitorial supplies, utility costs, etc.
3. Fixed charges: retirement contributions and insurance expenses.
4. Transportation costs: includes items such as driver salaries, vehicle replacement costs, maintenance costs, gas, oil, etc.

In this study, the first three components are combined and designated as operations costs. Transportation costs are handled in a category by themselves. In addition to these cost components, capital costs (cost of major structures) became important in considering district reorganization possibilities. Finally, the current costs incurred by districts in the study area are important comparisons for the linear programming results. Operations, transportation, capital, and current costs are discussed in turn.

A. Operations Costs

Economists use two methods to estimate cost functions: statistical [6] and synthetic [1]. The statistical approach typically involves estimating the parameters of a linear model via regression. A major limitation of this method is its reliance on past data with limited control over external items such as educational quality. The synthetic approach requires an explicit definition of the inputs required to provide a specific level or quality of education. These inputs are valued and summed to provide estimates of total costs. Through such a technique, the analyst has ultimate control over items entering cost calculations.

Several assumptions were made regarding formulation of a synthetic cost function. First, administrative costs were considered constant. These costs include such expenses as administration expenditures in the *School Finance Accounting Manual* [17] and consist primarily of expenses associated with the salary of the district superintendent and supporting staff. These costs currently represent about 2 percent of a district's total operating budget [8].

Second, teachers were assumed to teach no more than five classes per day on the average. Teachers for the five high schools in the study region taught an average of four to five classes each. Most high school teachers in Nevada are provided with at least one period per day (in a seven-period day) which can be devoted to class preparation. Thus, in the formulation of a cost function, a maximum load of five classes per teacher was assumed.

Third, the initial student-teacher ratio was assumed to be 20:1 or less. For the five schools under study, the student-teacher ratio varied from 7:1 at Eureka to 20:1 at Ely (based on current enrollment). In the urban school districts of Nevada, student-teacher ratios exceed 20:1 [15], but in most rural districts ratios are less than 20:1; thus, the latter ratio was assumed.

[2] In Nevada, school districts are organized on a county basis.

[3] The northern portion of Eureka County is omitted from the analysis because students in this area are bussed to Carlin in Elko County (see Fig. 2).

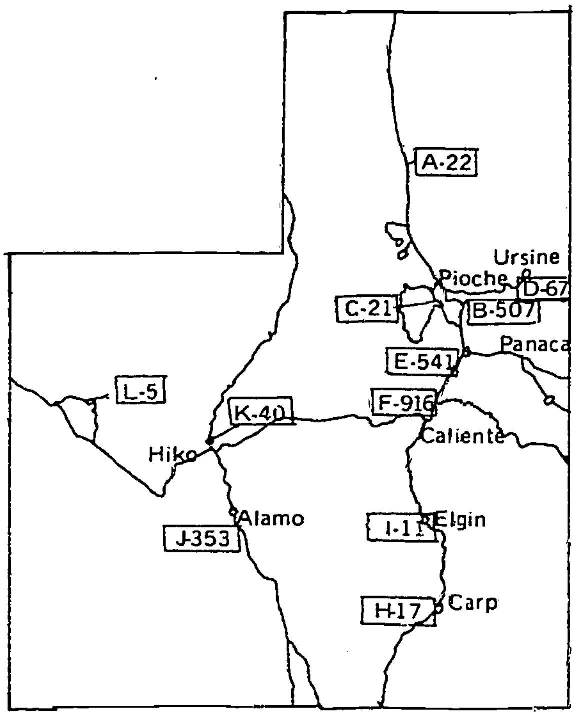


Figure 1. Lincoln County Population Groupings

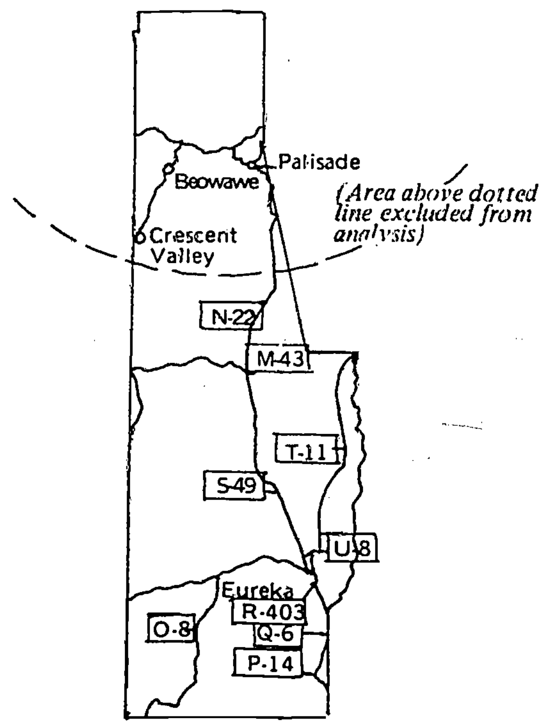


Figure 2. Eureka County Population Groupings

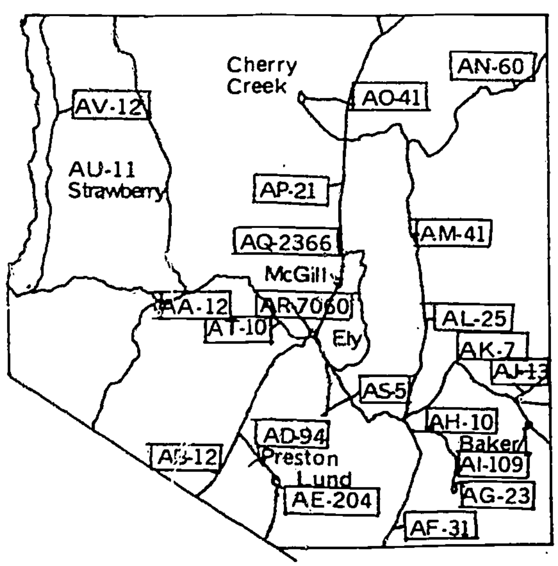


Figure 3. White Pine County Population Groupings

Analysis of data for the fiscal years 1970-1974 [15,18] indicated that about 96 percent of total operating expenditures (excluding administrative costs) are included in the categories of instruction, fixed charges, maintenance and operation, and transportation costs. Only these categories were considered in this study. Some of the costs not considered in the derivation of the synthetic cost function are adult education, food programs, and capital expenditures for equipment or structures.

Of the four categories, instruction costs were the largest. For 1970-1974, salaries comprised 93 to 94 percent of all costs in this category [15, 18]. Thus, salaries were assumed to equal 93 percent of total instruction costs in the development of a synthetic cost function. Total instruction costs were estimated by dividing the sum of instruction salary costs by 0.93. For these same years (1970-1974), average figures indicate that maintenance and operation costs are about 17 percent of instruction costs [15,17], and this figure was used in the study. Retirement benefit increases have steadily raised the relative amount of expenditures in the fixed charges category; but currently this category equals about 11 percent of expenditures in the instruction category, and 11 percent was used.

Salaries for teachers, principals, counselors, and clerical workers were estimated from district records. Teachers were assumed to receive an average salary of $11,200; principals, $16,000; counselors, $12,000; and clerical workers, $6,000. In smaller schools (less than 300 students) it was recognized that full-time principals, counselors, and clerical assistants were not justified [11]. Accordingly, salaries for principals, counselors, and clerks were pro-rated according to enrollment in smaller schools.

Currently, Nevada requires completion of at least 19 credits of high school course work for graduation. Nine and one-half of the credits are specified by law. The remaining 9-1/2 credits are selected from courses implemented by the school district. One credit is defined by the State Department of Education as "...120 hours of instruction or its equivalent per year" [16]. For this study, 1 unit or credit is defined as 120 hours of differentiated class instruction per year. Thus, the identical course taught more than once would not count as 2 units, but the same course taught at differing degrees of difficulty (tracking) would. In this study, the minimal curricular offering is 24 units. This is a very restricted type of program since all students receive virtually the same educational training, and there is little flexibility to develop individual needs and interests. Such a program is typical in smaller, rural Nevada high schools.

Using these assumptions and cost estimates, education per student costs were computed for program sizes of 24, 48, 72, and 84 units. These costs are depicted graphically in Fig. 4. Appendix A provides a more specific discussion of how operations costs are calculated.

B. Transportation Costs

Based on the population distribution within school districts [2], student locations and bussing routes were approximated by collecting the populace into groups (Figs. 1-3). Current enrollment figures were then gathered for the schools under study and a constant student density was computed by dividing the student enrollment at a particular school by the total population within that school's service area.

Service areas were specifically defined because the ratio of high school students to population was not uniformly consistent throughout the study area. For instance, 8 percent of the population within the Ely high school service area consisted of high school students whereas 13 percent of the population in the Alamo high school service area consisted of high school students. Differentiation was necessary to equate the number of students within a service area to the number of students currently enrolled at each school.

Using estimated vehicle mileage per district and current transportation budget figures, average bussing cost per miles of vehicle travel is about 50 cents for the three districts under study. White Pine School District busses about 429 students daily and normally uses vehicles varying in size from 9-passenger station wagons to 76-passenger busses. Dividing the number of students bussed daily (429) by the number of vehicles used (16), the average number of students per vehicle is 27. Since mileage cost is 50 cents per vehicle-mile, per student bussing cost per mile is about 1.85 cents (50 divided by 27). Due to the difficulty of collecting data, an average cost per student-mile was not determined for all three counties; but, it was expected that the more rural (less densely populated) character of Eureka and Lincoln school districts would raise this average cost per student per mile. For this reason, a cost of 2 cents per student per mile was initially used in this study.

C. Construction Costs

While all construction costs must necessarily be considered before any district reorganization is undertaken, such costs are not included in this study because of the difficulty in defining a standard cost for the construction of facilities. Existing facilities present widely differing degrees of quality ranging from converted quonset huts to modern

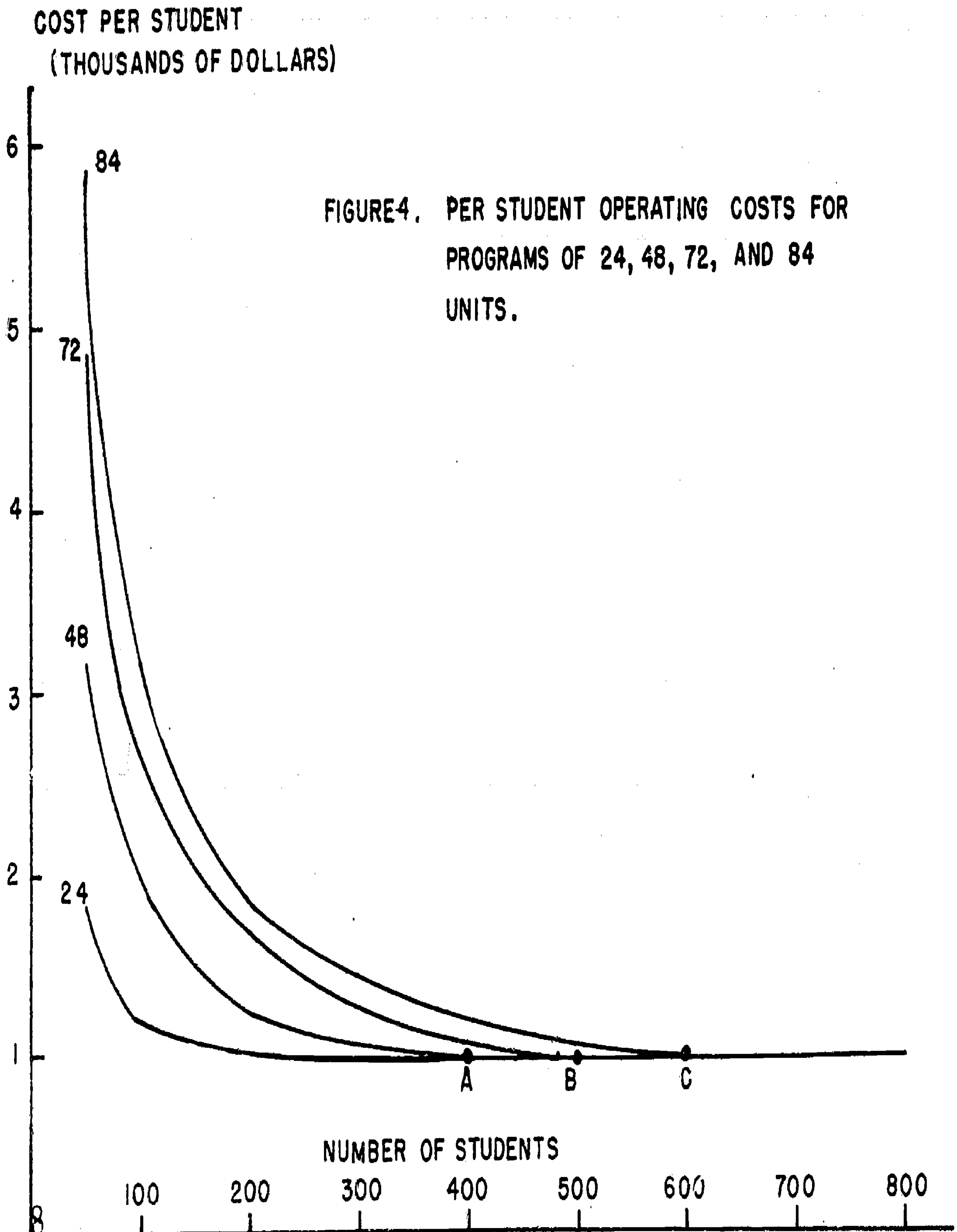


FIGURE 4. PER STUDENT OPERATING COSTS FOR PROGRAMS OF 24, 48, 72, AND 84 UNITS.

brick and glass structures with carpeting; and, construction costs would vary widely depending on the type of structure. Accordingly, this study concentrates on operating and transportation cost considerations. Construction costs are recognized as an integral part of the decision-making process, but such costs are discussed only briefly.

D. Current Costs

Based on district records, high school operating costs for White Pine School District were estimated at $935,000 or $1,140 per student. High school costs for Eureka School District were estimated to be $106,000 ($2,120 per student), and $355,000 or $1,644 per student for Lincoln County School District. Using a cost of 2 cents per student per mile, existent high school service area patterns, and assumed student locations, regional transportation costs were estimated at $40,000. Although this figure is not exact, it was felt to be a reasonable approximation and is presented for comparison.

IV. The Linear Programming Transportation Model

Once operating and transportation cost data were assembled, a linear programming transportation model [8] was used to determine the optimal (least cost) numbers, sizes, and location of schools. Specific details are in Appendix B. Essentially, the model computes the cost of alternative spatial organization (school numbers, sizes, and locations) and follows a set of rules which permits total cost (operations and transportation) to be minimized.

V. Linear Programming Results

A. Basic Solution with Program Quality Comparisons

Initial LP runs assumed a transportation cost of 2 cents per student-mile bussed, a bussing distance (one-way) no greater than 50 miles, a student-teacher ratio not to exceed 20:1, and a high school no smaller than the present one at Lund (50 students in grades 9-12). Runs were made for program sizes of 24, 48, 72, and 82 units. Regardless of standard of program quality assumed within the region, the same high school sizes and locations appear in solution (Table 1, runs 1 through 4). The LP program also provided a school at B for two students, a school at J for one student, and a school at AQ (Figs. 1-3) for four students. These small schools came into solution because it was explicitly stated that no student could be bussed more than 50 miles one way. Students for these small schools came from assumed student locations AV, and A (Figs. 1-3). This was a recurring problem, and for simplicity, any students falling outside the imposed bussing limit were assumed to be boarded at the nearest "solution" school in the region at an additional cost of $3.00 per student per school day. State law (Nevada Revised Statutes, Section 392.350) permits school districts to reimburse parents the costs of boarding children away from home at a maximum of $3.00 per child per school day. Such a procedure is commonly followed in practice.

Runs 1 through 4 also show that transportation costs would increase to about $59,000 a year under a least-cost situation as opposed to the current estimated transportation cost of $40,000. Optimal solutions show two fewer schools (Lund and Alamo high schools being eliminated), while the school location at Panaca is shifted to Caliente. Schools still appear at Eureka and Ely, with the Ely high school gaining 40 students bussed in from the Lund area. Students currently attending Panaca's high school are relocated in Caliente, while enrollment at Eureka high school remains essentially the same.

Current operating costs for existing high schools were estimated at $1,396,000. Reorganizing the district (run 2) would permit a minimal program quality of 48 units to be offered to all students within the region for $1,185,000, resulting in a substantial cost savings even after allowing for higher bussing costs. Currently, students at Lund, Eureka, and Alamo are exposed to much smaller program offerings. One should note that this solution does not diminish the quality of education at the Ely high school since an 84-unit program can be offered at a school with 818 students just as cheaply as a program size of 48 units.

However, reorganization also would presumably require large capital expenditures for the expansion of existing facilities at Ely to provide for increased enrollment and at Caliente for construction of a new school. Any reorganization would necessarily have to include such construction costs as an integral part of planning and making decisions.

B. Variation in Student-Teacher Ratios

Effects of permitting higher student-teacher ratios are presented in Table 2, runs 5 through 7.[4] For a 48-unit program assumed as a minimal offering, varying student-teacher ratios does not change the number, location, or

[4]When varying student-teacher ratios, it was implicitly assumed that there was no relationship between educational quality (curricular breadth) and student-teacher ratios.

TABLE 1

BASIC SOLUTIONS UNDER ALTERNATIVE LEVELS OF EDUCATIONAL QUALITY

Run No.	Program Size (Credits)	School Size and Location	Transportation Cost ($)	Operating Cost ($)	Combined Cost ($)	No. of Students Boarded
1	24	Caliente (216) Eureka (52) Ely (818)	59,000	1,084,000	1,143,000	7
2	48	Caliente (216) Eureka (52) Ely (818)	59,000	1,185,000	1,244,000	7
3	72	Caliente (216) Eureka (52) Ely (818)	59,000	1,353,000	1,412,000	7
4	84	Caliente (216) Eureka (52) Ely (818)	59,000	1,454,000	1,513,000	7

TABLE 2

SOLUTIONS WITH ALTERNATIVE STUDENT-TEACHER RATIOS

Run No.	S/T Ratio	School Size and Location	Transportation Cost ($)	Operating Cost ($)	Combined Cost ($)	No. of Students Boarded
5	20	Caliente (216) Eureka (52) Ely (818)	59,000	1,185,000	1,244,000	7
6	25	Caliente (216) Eureka (52) Ely (818)	59,000	1,051,000	1,110,000	7
7	30	Caliente (216) Eureka (52) Ely (818)	59,000	984,000	1,043,000	0

size of schools reported in run 2. Although changing the student-teacher ratio has an impact on the average cost per student function, such effects do not influence determination of optimal school locations. Thus, allowing the student-teacher ratio to increase from 20:1 to 25:1 results in an 11 percent reduction of operating costs. Permitting the student-teacher ratio to increase to 30:1 results in a 17 percent reduction of operating costs (from $1,181,000 to $980,000). All cost savings can be attributed to the school at Ely since the schools at Caliente and Eureka do not have a sufficient enrollment to permit student-teacher ratios of 25 or 30:1.

C. Variation in Transportation Costs

Although everyone is aware of the energy crisis and the dramatic price increases for gasoline and oil, these products comprise only a small proportion of total transportation costs. For instance, in White Pine School District, driver, clerical, and garage salaries composed about 86 percent of the total expenditures in the transportation account for the 1972-1973 operating year. Doubling gas and oil costs for that year would have increased total expenses in the transportation accoutn by only 14 percent (Table 3, runs 8 through 10). In other words, transportation costs would have to more than double before there would be any noticeable change in optimal school locations for planning purposes.

D. Variation in Allowable Bussing

Increasing one-way bussing from 50 to 75 miles raises bussing costs by $20,000, but results in a decreased operating cost of $105,000 for a net saving of $85,000 (Table 4, runs 11 through 13). Note that the facility at Eureka does not appear in solution and the seven boarded students come from Eureka County.

Assuming a one-way distance of 100 miles gives the same school sizes and locations as run 12, but eliminates the necessity of boarding students. Transportation costs increase $2,000 over run 12 but boarding costs are eliminated; so there is actually a small decrease in total costs as a consequence of extending the bussing limit from 75 to 100 miles.

Before any bussing limits are extended, administrators and educators would have to consider the effects of bussing on students. Lu and Tweeten [9] report that bussing does have some negative effects on achievement and performance. For instance, when students riding busses more than 1 hour per day were compared with students riding busses less than 1 hour per day, it was discovered that student achievement (measured by test scores) was lower for the first group. The authors concluded that increased bus riding time reduces achievement. Consequently, educators would have to ask whether the cost savings of reorganization justifies increasing bussing time and risking the possibility of adversely affecting student performance.

E. Present Facilities Solutions

Thus far we have varied several parameters in the LP model. However, there may also be instances when educators desire to see the results of a solution which considers only specified locations as possible school sites (Table 5, runs 14 through 15). Such a procedure would permit analysis of economic benefits accruing as a result of school consolidation and closure of small schools. Another potential use would be to incorporate long range population shifts to produce expanded enrollments in specific localities. Run 14 indicates the operating costs for a standardized minimal program of 48 units using the existent five school locations at Ely, Lund, Eureka, Panaca, and Alamo would be $1,436,000. Eliminating the locations at Lund and Ely (run 15) reduced estimated operating costs by $255,000, but transportation costs increased $23,000, resulting in a net saving of $232,000 per year.

VI. Conclusions

The difficulty of maintaining and financing adequate school programs, particularly in rural areas, suggests that methods be devised to analyze and improve the efficiency of school district operation. Accordingly, this study sought: (1) to develop a standardized cost function for different educational program sizes (quality); (2) to investigate the interaction of cost, quality, and efficiency in the formulation of educational programs; (3) to present a LP model to identify optimal school district organization; (4) to apply the model in a practical analysis of a rural region of Nevada; and (5) to estimate the economic benefits obtained by district reorganization of selected Nevada high schools.

The synthetic cost function exhibited characteristics normally attributed to such functions [4,10]. Per student costs declined when high school size increased as a consequence of better resource utilization and, in particular, more efficient use of teachers. For larger schools, the derived cost function indicated that program quality could be substantially improved at little or no increase in per student operating costs. Thus, larger school sizes appear to be

TABLE 3

SOLUTIONS WITH VARIATIONS IN TRANSPORTATION COSTS

Run No.	Mileage Cost (cents)	School Size and Location	Transportation Cost ($)	Operating Cost ($)	Combined Cost ($)	No. of Students Boarded
8	2	Caliente (216) Eureka (52) Ely (818)	59,000	1,185,000	1,244,000	7
9	4	Caliente (216) Eureka (52) Ely (818)	119,000	1,185,000	1,204,000	7
10	6	Caliente (216) Eureka (52) McGill (197) Ely (621)	132,000	1,269,000	1,401,000	7

TABLE 4

SOLUTIONS WITH VARYING BUSSING LIMITS (MILES ONE WAY)

Run No.	Bussing Limit (miles one way)	School Size and Location	Transportation Cost ($)	Operating Cost ($)	Combined Cost ($)	No. of Students Boarded
11	50	Caliente (216) Eureka (52) Ely (818)	59,000	1,185,000	1,244,000	7
12	75	Caliente (214) Ely (872)	79,000	1,080,000	1,159,000	7
13	100	Caliente (214 Ely (872)	81,000	1,076,000	1,157,000	0

TABLE 5

SOLUTIONS WHEN SELECTED LOCATIONS ARE FORCED INTO SOLUTION

Run No.	"Present Facilities"	School Size and Location	Transportation Cost ($)	Operating Cost ($)	Combined Cost ($)	No. of Students Boarded
14	Not Applicable	Lund (40) Panaca (165) Alamo (51) Ely (780) Eureka (50)	40,000	1,436,000	1,476,000	0
15	Not Applicable	Panaca (216) Eureka (52) Ely (818)	63,000	1,185,000	1,248,000	0

justified not only because of cost savings, but also because of being able to offer improved educational quality. In remote rural areas, however, larger school sizes can be achieved only by increasing student bussing and closing down smaller schools.

Since increased bussing involves a social cost to the student as well as an economic cost to the school district, the community must resolve the question of economic savings and improved educational opportunity versus student and parent inconvenience suffered as a consequence of bussing. In many communities, the school also serves as a gathering place for community functions. Thus, administrators must also weigh the social cost to the community if small rural schools are closed. Results presented provide information which might be useful in the decision-making process.

Using the synthetic cost function and estimated per mile bussing cost, a linear programming transportation model was used to identify optimal (least-cost) high school locations for the three district regions of Eureka, Lincoln, and White Pine counties. It was found that reorganization would provide the greatest cost savings for an assumed quality of education by closing two existing high schools in this region and relocating a third. Changes in assumed quality (curricular breadth) did not affect either high school size or location when different program sizes were assumed as a minimal standard of education within the region. The analysis suggests the economic feasibility of reorganization.

Variations in assumed parameters provided interesting insights and exhibited the flexibility of the linear programming model as an evaluative tool to be used by educational administrators. For example, the costs and benefits accruing to the region as a consequence of varying student-teacher ratios was examined. It was estimated that increasing the student-teacher ratio from 20:1 to 30:1 would reduce operating costs 17 percent. By inserting assumed transportation cost increases into the LP model, it was possible to assess the sensitivity of optimal school locations to variations in transportation costs. Results show that transportation costs would have to increase by 200 percent before they became a critical factor. However, changing assumed bussing mileage limits did significantly affect location and size of least-cost regional organization patterns. Assuming no student could be bussed further than 50 miles (one way) resulted in high schools at Ely, Caliente, and Eureka. Assuming a 75- or 100-mile bussing limit resulted in only two school locations–Ely and Caliente.

One major shortcoming of this study is that it did not explicitly consider the dollar cost of facility construction and expansion as a consequence of district reorganization. Such consideration is an integral part of any reorganization planning and could be integrated into the LP model to provide a total economic impact analysis of district reorganization. While such an integrative process was beyond the resources and timetable available for this study, such an integration would be the logical conclusion and is suggested for future research.

SYNTHETIC COST CALCULATIONS

Proceeding from the assumptions and cost estimates, it is possible to estimate the operating cost for an educational program of a given course diversity and a specified number of students. Given a 24-unit curriculum and a student enrollment of 50, the operating cost for this program would be calculated in the following manner.

First, the number of classes resulting from required courses should be determined. Since there are less than 20 students in any particular grade, it would be unnecessary to double up on required classes which were assumed to total 10 credits. Given a maximum teacher load of five courses per teacher, 10 credits will require two teachers. Fourteen additional credits are assumed to be electives and three additional teachers will be required, bringing the number of required teachers to five. Although not of consequence in this example, the student-teacher ratio cannot be allowed to exceed 20:1. If this had been the case, additional teachers would be assumed until the ratio is reduced to the 20:1 limit. Continuing with the example, clerical help and counseling services are prorated as follows: 5/6 x $6,000 = $5,000 for clerical salaries; and, $40 x 50 students = $2,000 for counseling services. The principal's duties would be minimal in a school this size and are prorated at $60 x 50 students (based on a full-time salary of $16,000) for a cost of $3,000. Teacher salaries total $56,000 ($11,200 x 5) and total salary costs in the instruction category equal $66,000. Since salary costs represent 93 percent of total instruction costs, total instruction costs equal $90,968 ($66,000 divided by 0.93). Maintenance and operation costs equal 17 percent of instruction costs or $12,065. Fixed charges equal 11 percent of instruction costs or $7,806.

Itemization of calculated operating costs are presented:

INSTRUCTION SALARIES	$66,000	
INSTRUCTION EXPENSES	4,968	
TOTAL INSTRUCTION COSTS		$70,968
MAINTENANCE & OPERATION		12,065
FIXED CHARGES		90,839

$$\text{Cost Per Student} = \frac{\text{Total Cost}}{\text{Number of Students}} = \$1{,}817 \text{ Per Student}$$

Per student costs for other school and program sizes can be calculated in a similar fashion. For example, per student costs have been calculated for 24-unit, 48-unit, 72-unit, and 84-unit programs. Results are shown in Fig. 1. Note that this is a "smoothed" functional presentation of the derived cost curve. Each cost curve is actually discontinuous because of the discrete nature of the data. The discontinuities arise as a consequence of the student-teacher ratio which is assumed to be 20:1. A simplified flow chart describing the step-by-step operations used to compile the cost function is presented in Fig. 5.

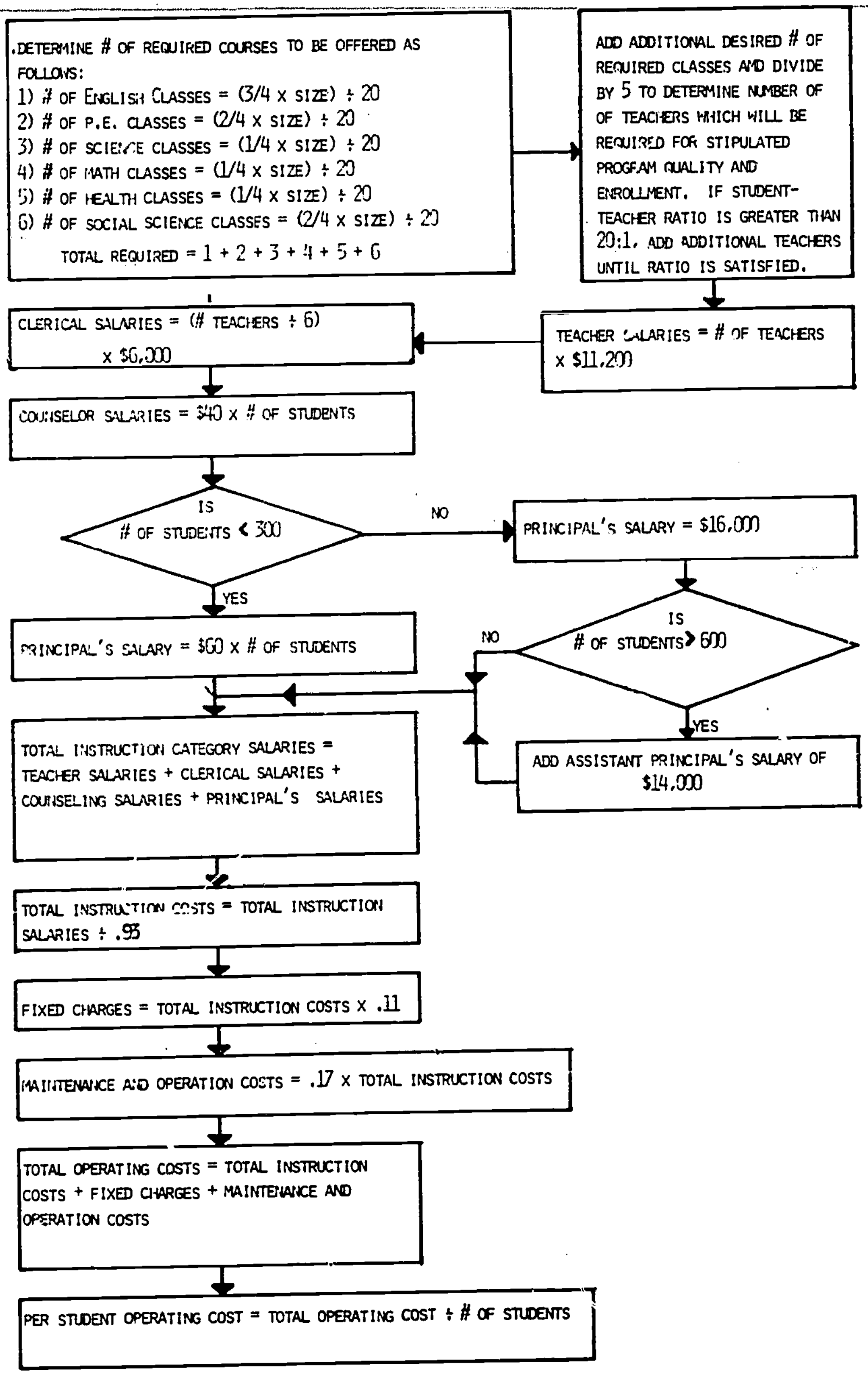


FIGURE 5. SCHEMATIC DIAGRAM OF COST CALCULATIONS

APPENDIX B

THE LINEAR PROGRAMMING TRANSPORTATION MODEL

The objective of the LP model is to minimize the combined cost of school operation and transportation expenses. Mathematically, the problem is to:

1) $$\text{minimize } TC = \sum_{i=1}^{m} \sum_{j=1}^{n} X_{ij} (t_{ij} + C_j)$$

subject to the constraints

2) $$\sum_{j=1}^{n} X_{ij} = S_i, i = 1, ..., m$$

3) $$\sum_{i=1}^{m} X_{ij} = D_j, j = 1, ..., n$$

4) $$X_{ij} > 0$$

5) $$\sum_{i=1}^{m} S_i = \sum_{j=1}^{n} D_j$$

where:

TC = total cost of school operation

X_{ij} = number of students residing at location i who are sent to school j

S_i = number of students residing at location i

D_j = number of students at the j^{th} school

t_{ij} = transportation cost of sending a student from location i to school j

C_j = operation cost of a school at the j^{th} location

m = total number of student locations

n = total number of possible school locations

It is assumed that the per student cost of school operation is a function of school size and that larger schools have smaller per student operating costs. Since there are two classes of unknowns (operating costs and school sizes and locations), the solution is iterative in nature [3,7,10]. Thus, to use the LP model to derive least cost school locations, it was necessary to initially assume a value for C_j. With operating costs specified, the problem was then solved in the usual manner. These results are then checked to see if they are consistent with the operating cost assumed. If not, another cost is specified and the problem is run in an iterative fashion until the program converges on a solution which optimizes school locations and sizes and is consistent with the operating costs previously assumed. Typically, it took no more than five or six iterations to converge on an optimal solution.

REFERENCES

1. Black, Guy. "Synthetic Method of Cost Analysis in Agricultural Marketing Firms," *Journal of Farm Economics*, XXXVII (May, 1955).

2. Bradhurst, Stephen. "Nevada Population Distribution in 1970." State of Nevada, Water and Related Land Resource Areas with Nevada Population Distribution in 1970, Division of Water Resources, August, 1972.

3. Ching, C.T.K. "An Iterative Procedure for Solving Physical Distribution Problems," *Transportation Journal*, X (Spring, 1971).

4. Cohn, Elchanan. "Economics of Scale in Iowa High School Operations," *The Journal of Human Resources*, III (Fall, 1968).

5. Coleman, James S. *et al.* *Equality of Educational Opportunity.* Washington: U.S. Government Printing Office, 1966.

6. Johnston, J. *Statistical Cost Analysis.* New York: McGraw-Hill, 1960.

7. King, Gordon, and Samuel H. Logan. "Optimum Location, Number and Size of Processing Plants with Raw Product and Final Product Shipments," *Journal of Farm Economics*, XXXXVI (February, 1964).

8. Llewellyn, Robert W. *Linear Programming.* New York: Holt, Rinehart and Winston, 1964.

9. Lu, yao-Chi, and Luther Tweeten. "The Impact of Bussing on Student Achievement," *Growth and Change*, IV (October, 1973).

10. Mooney, Michael B. "Planning a Least Cost High School System in New Hampshire." Unpublished Master's thesis, University of New Hampshire, 1973.

11. Ovard, Glen F. *Administration of the Changing Secondary School.* New York: Macmillan Co., 1966.

12. Purdy, Ralph D. *et al.* "Guidelines for School District Organization." A Project Report by the Great Plains School District Organization Project, The State Department of Education, Lincoln, Nebraska, July, 1968.

13. Raymond, Richard. "Determinants of the Quality of Primary and Secondary Public Education in West Virginia," *Journal of Human Resources*, III (Fall, 1968).

14. Sadler, Ronald A., and C.T.K. Ching. *Determinants of Educational Quality in Nevada*, Agr. Exp. Sta. Bull. No. 32, University of Nevada Reno, February, 1974.

15. State of Nevada, Department of Education. *Biennial Report of the Superintendant.* Selected issues, 1968-1972.

16. State of Nevada, Department of Education. *Nevada High School Graduation Requirements: Rules and Regulations.* January, 1973.

17. State of Nevada, Department of Education. *School Finance Accounting Manual.* January, 1970.

18. State of Nevada, Department of Education. *Summary of Nevada School Budget for 1973-1974.*

19. Voelker, Stanley W., and Thomas K. Ostensen. *Rural-Urban Quality Differentials in North Dakota's Public School System*, Agr. Econ. Report No. 67, Agr. Exp. Sta., North Dakota State University, Fargo, March, 1970.

20. White, Freddie Cad. "A Quantitative Analysis of Factors Affecting Elementary and Secondary Schooling Quality in Oklahoma with Economic Applications in Rural Areas." Unpublished doctoral dissertation, Okoahoma State University, May, 1972.