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PUPIL TRANSPORTATION: A COST ANALYSIS AND PREDICTIVE MODEL

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IN COOPERATION WITH

DEPARTMENT OF TRANSPORTATION
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PREFACE

In July of 1973 the Governor's Office of Educational Research and Planning of the State of Texas was established by Governor Briscoe. Its primary purpose was to develop a comprehensive school finance plan for Texas. Twenty areas of inquiry were identified including pupil transportation. The diversity of these areas made it quite impossible, considering the limited funds and personnel available, to conduct all research in-house. Consequently, various outside resources were tapped. In the area of transportation, the Council for Advanced Transportation Studies (CATS) at The University of Texas at Austin was utilized.

In April 1973, CATS received a research grant from the U.S. Department of Transportation (DOT) entitled "Transportation to Fulfill Human Needs in a Rural-Urban Environment" (Contract No. DOT-OS-30093). Element I of this research grant, entitled "Access to Essential Services," was concerned with accessibility of rural/urban populations to essential services, including public education. To eliminate duplication, a joint research effort on pupil transportation was formulated between the Governor's Office and CATS. The necessary interagency contracts were executed and Mr. David Venhuizen was retained by CATS as the primary researcher, working in conjunction with Dr. Kelly Hamby of the Governor's Office and Dr. Ronald Briggs of CATS. This Research Memorandum reports some of the results of this research effort.

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INTRODUCTION

School bus transportation is the only type of mass transit operating in all parts of the United States today. In many rural areas it is the only form of transportation available apart from the private automobile. In many urban areas the school transportation system rivals the municipal transit system in capacity, scope and budget. Despite the importance of the systems themselves, and the hints they might provide for the organization of transportation alternatives to the automobile in areas, particularly rural regions, where alternatives do not presently operate, there is a relative paucity of research on pupil transportation systems. This paper presents a study of such systems in Texas.

The ultimate aim of the research was to design a formula for the equitable allocation of state monies to local school districts for pupil transportation. In the process data were collected on the system characteristics and operating costs of approximately one-third of the more than 1,000 school districts engaged in pupil transportation in the state. These data were used to develop a model for predicting actual pupil transportation costs by school district. Based upon this predictive model a formula was designed for the allocation of state monies to local school districts. This paper analyzes the system characteristics and operating costs of pupil transportation systems in Texas, and describes the model for predicting operating costs in comparison to other models developed to predict the costs of urban transit. The allocation formula, which is of lesser general interest, is described elsewhere.[1]

DATA COLLECTION

There are four distinct categories of school transportation expenditures in Texas. First are the operational expenditures for regular

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[1]David Venhuizen, "The Challenge of Restructuring State Funding of School Transportation in Texas," unpublished M.Sc. thesis, Department of Civil Engineering, The University of Texas at Austin, 1975.

pupil transportation. Then, with somewhat different cost characteristics, there are operational expenses for special education (handicapped) pupil transportation. The third category of expenditures is bus replacement, an expense common to both of the above systems. Finally, there is contracted transportation which itself has two different facets--contracting with a public carrier for route operation, and contracting with pupils' parents for individual transportation by automobile. The main thrust of this report is toward operational expenditures for regular transportation which exclude allowances for bus purchase or depreciation.

Because of the size and diversity of the state, a two stage research strategy was developed. In the first stage, a sample of 22 school districts was initially selected and extensive information on pupil transportation systems operating in the 1972-1973 school year was obtained for each by personal interviews and from Pupil Transportation Reports and School District Audit Reports held by the Texas Education Agency (TEA). This sample was later expanded to 49 districts using a mail-out questionnaire. These school districts comprised all those classified as "exemplary" by the Governor's Office of Educational Research and Planning.[2] Some additional districts were included either to ensure complete geographical coverage of the state, or because they were known to keep particularly good transportation records. The sample included a broad range of district sizes and types of communities served (Table 1). These first stage data, referred to as the detailed sample, provide detailed information on the characteristics of pupil transportation systems, and were utilized to explore predictive models for transportation costs. They yielded a rough outline of an appropriate model, an associated formula for allocating state monies to local school districts, and an indication of the data necessary to finalize the model and formula.

In the second stage of the research a less detailed data set was obtained for 331 school districts.[3] These data included total regular

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[2]Exemplory districts were those considered "worthy of imitation" by knowledgable educators in the state.

[3]This number includes those in the detailed sample.

TABLE 1. SCHOOL DISTRICTS COMPRISING THE DETAILED SAMPLE

School District	County	Population of Legal City	Average Daily Attendance
Central City (over 100,000)			
Amarillo	Potter	12,010	24,995
Austin	Travis	251,808	51,241
Corpus Christie	Nueces	204,525	39,936
Dallas	Dallas	844,401	174,715
El Paso	El Paso	322,261	57,195
Houston	Harris	1,232,802	191,842
Lubbock	Lubbock	149,101	30,716
San Antonio	Bexar	654,153	62,779
Central City (under 100,000)			
Abilene	Taylor	89,653	17,338
Edinburg	Hidalgo	17,163	8,223
Killeen	Bell	35,507	12,886
Odessa	Ector	78,380	21,171
Port Arthur	Jefferson	57,371	13,297
San Angelo	Tom Green	63,884	13,545
Temple	Bell	33,431	7,204
Tyler	Smith	57,770	14,314
Suburban (Central County)			
Alamo Heights	Bexar	6,933	4,311
Arlington	Tarrant	90,643	22,103
Cypress-Fairbanks	Harris		8,677
Deer Park	Harris	12,773	6,025
Del Valle	Travis		3,709
Eanes	Travis		1,363
Manor	Travis	940	737
Mesquite	Dallas	55,131	17,448
North East	Bexar		27,159
Pasadena	Harris	89,277	31,770
Richardson	Dallas	48,582	29,866
Spring Branch	Harris	39,333	
Ysleta	El Paso		34,337

TABLE 1. SCHOOL DISTRICTS COMPRISING THE DETAILED SAMPLE (con't)

School District	County	Population of Legal City	Average Daily Attendance
Suburban (Non-central County)			
Canyon	Randall	8,333	2,749
Columbia-Brazoria	Brazoria		2,398
Comal	Comal		2,385
Henrietta	Clay	2,827	720
San Marcos	Hays	18,860	4,207
Waxahachie	Ellis	13,452	3,396
Urban Place			
Andrews	Andrews	8,625	2,417
Bastrop	Bastrop	3,112	1,780
Breckenridge	Stephens	5,944	1,413
Burnet	Burnet	2,864	1,461
Fort Stockton	Pecos	8,283	2,865
Georgetown	Williamson	6,395	1,926
Hereford	Deaf Smith	13,414	5,139
Llano	Llano	2,608	1,006
Spearman	Hanford	3,435	1,000
Rural			
Albany	Schaleford	1,978	494
Goliad	Goliad	1,709	1,125
Johnson City	Blanco	767	367
Rankin	Upton	1,105	428
Wall	Tom Green		502

Note: See footnote 7 for grouping criteria.

student transportation cost, average daily attendance (ADA), pupils transported daily, daily route miles travelled, number of routes operated daily, number of buses used, and the area of the school district. The cost data were obtained from TEA School District Audit Reports, and the physical data from mail-out questionnaires. The sample was chosen so that every geographical area of the state was included and the ADA distribution of the sample matched that of the state. This data set, referred to as the expanded sample, was used to finalize and evaluate the predictive model and associated allocation formula.

Several problems were encountered in collecting and interpreting the data sets which bear heavily on the reliability of the data and the nature of the predictive model. In the main, these problems arose from the present method by which state monies are allocated to local districts for transportation, and the records which are consequently maintained. Because monies are only allocated to pay for the transportation of "eligibles" (those students living more than two miles from their school) on routes approved by TEA, records were not always maintained on the number of ineligibles transported,[4] nor of the actual bus mileage driven as against the length of the approved "paper" route. In addition, problems were imposed by the inclusion in transportation records of items other than normal pupil transportation between place of residence and school campus. For instance, expenditures on co-curricular activities and upon gasoline and maintainance expenditures for district vehicles other than school buses, were often inseparable from school bus costs.[5] Finally, the administrative and clerical costs incurred in setting up and running the pupil transportation system were difficult to separate from general district administrative costs.

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[4]Ineligibles are those students resident within two miles of their school. Any costs incurred in their transportation must be borne by local school districts and is not eligible for state reimbursement.

[5]Co-curricular activities include field trips and sporting events.

CHARACTERISTICS OF PUPIL TRANSPORTATION IN TEXAS

The Statewide System

In Texas, no data are available on a statewide basis on the total number of pupils transported, school bus routes operated or mileages driven, or on actual expenditures for pupil transportation. Information is available only on pupils and routes eligible for state reimbursement, and for the magnitude of this reimbursement (Table 2). In the 1973-1974 school year 670,000 eligible students were transported on nearly 9,000 routes with a combined mileage of almost 550,000. State reimbursements amounted to $27 million for regular transportation - approximately 23¢ per student per day, assuming a 180 day school year. This reimbursement was considerably below actual costs since sample data indicate that operations costs alone range from 21¢ to 69¢ for the six groupings of school districts examined in the expanded sample. Extrapolations for 1972-1973 utilizing the predictive model developed in this study suggest total statewide operations costs for regular transportation of $46.5 million, as against a state reimbursement of $26.7 million to cover both operations and bus replacement costs.[6]

Some of the changes in the system over the last four years are indicated in Table 3. Both the number of regular routes and regular pupils transported have been steadily increasing. During the last two years the rate of increase in state allocations has not kept up with increases in the number of regular students transported. However, the difference has been insufficient to significantly impact costs per pupil per day (Table 2). Decreases in the rate of increase of special education transportation reflect phasing in of a program initiated in the 1970-1971 academic year. Reimbursement here is at a flat rate of $150 per pupil per year or 83¢ per day. This is considerably higher than the regular student reimbursement rate (23¢) and reflects the higher costs involved in special education

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[6]This extrapolation was obtained by multiplying the total cost predicted by the model for each group of school districts by the ratio of the sample N to the state N for each group (see Table 12).

TABLE 2. THE MAGNITUDE OF THE TEXAS PUPIL TRANSPORTATION SYSTEM ELIGIBLE FOR STATE REIMBURSEMENT

	1970-1971	1971-1972	1972-1973	1973-1974
# of Regular Transportation Routes	7,973	8,312	8,574	8,948
Total Daily Route Miles	512,517	512,895	572,493	549,703
# of Pupils Transported on Regular Routes	583,231	595,955	636,635	670,353
# of Special Education Pupils Transported	13,015	15,766	18,357	19,435
State Allocation for Regular Transportation ($,000)	24,068	25,185	26,747	27,168
State Allocation for Special Education Transportation ($,000)	1,920	2,407	2,796	2,913
Average Allocation Per Pupil Per Day ($) (Regular Transportation)	.23	.23	.23	.23
Avarage Allocation Per Pupil Per Day ($) (Special Education)	.82	.85	.85	.83

transportation. Unfortunately, the actual costs associated with special education transportation are not known.

The Provision of Pupil Transportation (Detailed Sample)

The total amount of pupil transportation provided, including regular and special students, eligibles and ineligibles, varies quite markedly between school districts. For the 49 districts in the detailed sample the percentage of regular students transported relative to ADA varies from a low of 1.5% (Corpus Christi) to a high of 97.6% (Wall) with a sample value of 15.1% (Table 4). This variability is clearly associated with the type of community which the school bus system serves (Table 5).[7] In the larger central cities less than 12% of all pupils are transported, whereas in the smaller central cities and urban places this figure is generally between 10% and 30% (Table 4). Rural districts, together with those in the non-central counties of SMSA's, transport an average of 60% of their pupils. This association can be hypothesized to follow from two factors: (1) the geographical distribution of students within the district, and (2) local decisions concerning the transportation of ineligibles.

One index of the geographical distribution of students within a district is provided by pupil areal density (PAD) - ADA divided by the area of the school district. Low as against high PAD's indicate greater dispersal of students. Consequently, as PAD's decrease a given size school must draw upon a spatially more extensive catchment area. This increases distances pupils must travel, and expands the demand for transportation.

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[7] School districts were classified according to which of the following community types they served: (1) Central Cities over 100,000 - central cities of Standard Metropolitan Statistical Areas (SMSA) as defined by the Office of Management and Budget in April 1974 with populations greater than 100,000; (2) Central Cities below 100,000 - central cities as defined above but with populations less than 100,000; (3) Suburban Central County - areas within the central county of SMSA's but outside the central city; (4) Suburban Non-Central County - areas within non-central counties of SMSA's (5) Urban Places - cities with populations greater than 2,500 but not part of SMSA's (6) Rural - places outside of SMSA's containing no town greater than 2,500. Note that school district boundaries do not necessarily conform to city or county boundaries.

TABLE 3. ANNUAL PERCENTAGE CHANGES IN THE TEXAS PUPIL TRANSPORTATION SYSTEM ELIGIBLE FOR STATE REIMBURSEMENT

	% Changes		
	70-71 to 71-72	71-72 to 72-73	72-73 to 73-74
# of Regular Transportation Routes	4.25	3.15	4.36
Total Daily Route Miles	0.07	11.62	-3.98
# of Pupils Transported on Regular Routes	2.18	6.83	5.30
# of Special Education Pupils Transported	21.14	16.43	5.87
State Allocation for Regular Transportation	4.64	6.20	1.57
State Allocation for Special Education Transportation	25.37	16.16	4.18

TABLE 4. THE PROVISION OF PUPIL TRANSPORTATION IN 49 TEXAS SCHOOL DISTRICTS, 1972-1973 ACADEMIC YEAR

School District	Pupil Areal Density (PAD)	% of ADA Transported (Regular)	% of ADA Transported (Special)	Ratio: Total Transported/ Eligibles	Cost Per Pupil Per Day
Central City (over 100,000)					
Amarillo	355.86	4.1	0.00	1.00	.189
Austin	178.54	12.1	.98	1.00	.376
Corpus Christie	255.89	1.5	.87	1.00	.566
Dallas	283.17	12.2	1.02	1.00	.250
El Paso	262.22	11.0	.29	1.70	.287
Houston	616.86	7.7	1.91	1.47	.343
Lubbock	349.06	1.5	.55	1.00	.729
San Antonio	812.73	5.3	.92	1.10	.105
Central City (under 100,000)					
Abilene	169.85	11.7	1.44	1.08	.213
Edinburg	8.70	45.8	.18	1.18	.262
Killeen	27.07	28.4	.38	1.00	.192
Odessa	23.34	20.8	1.04	1.10	.413
Port Arthur	260.73	12.4	1.11	1.00	.342
San Angelo	67.07	11.5	.48	1.06	.253
Temple	144.08	3.3	0.00	1.00	.434
Tyler	76.17	24.8	1.10	1.07	.227

TABLE 4. THE PROVISION OF PUPIL TRANSPORTATION IN 49 TEXAS SCHOOL DISTRICTS, 1972-1973 ACADEMIC YEAR (con't)

School District	Pupil Areal Density (PAD)	% of ADA Transported (Regular)	% of ADA Transported (Special)	Ratio: Total Transported/ Eligibles	Cost Per Pupil Per Day
Suburban (Central County)					
Alamo Heights	479.00	5.0	0.00	1.06	.114
Arlington	241.77	17.2	.48	1.00	.258
Cypress-Fairbanks	46.65	86.7	.58	1.22	.258
Deer Park	158.53	32.1	.71	1.76	.452
Del Valle	21.91	56.6	0.00	1.00	.239
Eanes	45.03	50.6	0.00	1.93	.218
Manor	8.17	70.3	0.00	1.00	.262
Mesquite	295.75	9.9	1.39	1.00	.249
North East	204.27	27.1	1.29	1.00	.249
Pasadena	418.26	23.1	2.06	1.98	.290
Richardson	771.23	16.7	.48	1.36	.144
Spring Branch	874.86	48.2	.89	2.46	.205
Ysleta	553.82	5.6	.85	1.00	.189
Suburban (Non-central County)					
Canyon	3.86	56.5	0.00	1.00	.314
Columbia-Brazoria	10.92	80.7	0.00	1.35	.199
Comal	4.04	85.4	0.00	1.05	.298
Henrietta	1.69	34.7	0.00	1.08	.411
San Marcos	20.79	61.2	0.00	1.00	.153
Waxahachie	17.68	38.1	0.00	1.02	.156

TABLE 4. THE PROVISION OF PUPIL TRANSPORTATION IN 49 TEXAS SCHOOL DISTRICTS, 1972-1973 ACADEMIC YEAR (con't)

School District	Pupil Areal Density (PAD)	% of ADA Transported (Regular)	% of ADA Transported (Special)	Ratio: Total Transported/ Eligibles	Cost Per Pupil Per Day
Urban Place					
Andrews	1.62	18.1	0.00	1.19	.844
Bastrop	4.17	65.2	0.00	1.06	.284
Breckenridge	1.76	18.4		1.08	.761
Burnet	2.23	55.2	0.00	1.00	.325
Fort Stockton	0.95	21.1	0.00	1.05	.547
Georgetown	11.12	29.5	0.00	1.14	.273
Hereford	7.19	29.7	.64	1.00	.334
Llano	1.12	57.0	0.00	1.00	.423
Spearman	2.15	19.7	0.00	1.00	.956
Rural					
Albany	0.84	26.3	0.00	2.28	.682
Goliad	1.39	69.2	0.00	1.00	.315
Johnson City	.74	43.1	0.00	1.00	.474
Rankin	.49	38.8	0.00	1.00	.811
Wall	1.34	97.6	0.00	1.02	.223

TABLE 5. THE PROVISION OF PUPIL TRANSPORTATION BY COMMUNITY TYPE: 49 TEXAS SCHOOL DISTRICTS, 1972-1973

	Mean Pupil Areal Density	% of ADA Transported (Regular)	% of ADA Transported (Special)	Ratio: Total Transported/ Eligibles[a]
Central City (over 100,000)	389.20	8.5	1.14	1.12
Central City (below 100,000)	97.13	19.3	.84	1.06
Suburban (Central County)	316.87	26.1	0.98	1.37
Suburban (Non-central County)	9.83	60.8	0.00	1.08
Urban Place	3.59	32.3	0.00	1.06
Rural	0.96	59.1	0.00	1.26

[a]"Total Transported" includes both eligibles and ineligibles, but not special students.

Table 5 clearly indicates that community types are characterized by school districts with differing PAD's and that as PAD declines the proportion of students transported increases.

A second index of the geographical dispersion of students is the number of pupils transported who are presently eligible for state reimbursement of transportation costs. This group comprises students living more than two miles from their school. It is apparent from Table 4 that most districts transport only eligibles. In more than 70% of the districts the proportion of ineligibles to eligibles is less than 10%. Consequently, much of the variability between communities in the proportion of students transported follows from differences in the number of students resident beyond the two-mile limit.

Local decisions as to the transportation of ineligibles also impact the overall proportion of students transported. Suburban districts within the central counties of SMSA's appear to transport a higher than average number of ineligibles (Table 5).[8] The cost of transporting ineligibles must be borne by the school district itself. The higher proportion of ineligibles transported by suburban districts may reflect the enhanced ability of these districts to pay for the transportation of ineligibles, given their probable affluence relative to central city and rural districts.

The Cost of Pupil Transportation (Detailed Sample)

Total cost per student transported varies between 10¢ and 96¢ with an overall value of 27¢ for the 49 school districts in the detailed sample.[9] From Table 6 it is apparent that these costs are associated with the type of community served. Urban places and rural areas have a cost per student transported almost twice that of suburban communities, with central cities occupying an intermediate position. This differentiation appears to be based upon variability between communities on three factors: the spatial

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[8] Note that the relatively high value for rural areas is accounted for by one district which transported the fewest number of students in the sample.

[9] The data include both special and regular transportation.

distribution of students, local cost levels and salary scales, and the number of special and ineligibles relative to total students transported.

The greater spatial dispersion of students in small urban places and rural communities as indexed by PAD (Table 5) results in more than twice as many miles being driven per student transported in these communities as against central city and suburban areas (Table 5). Consequently, costs per student transported are high in these areas. Local cost levels and salary scales (Table 7) also impact costs per student. The relatively high costs per student incurred by the central city districts despite their low number of miles per student is, in part at least, attributable to higher bus driver salaries. Also, it is likely that a similarly higher level holds for the salaries of administrative and maintenance personnel. The particularly low costs per student enjoyed by non-central county suburban districts appears to derive from their combination of low bus driver salaries and moderate number of miles per student transported.

The low costs per student transported, despite higher salary levels, in the central county suburban districts appears to be based upon a particularly low mileage per student transported. The low mileage is probably a consequence of transporting a larger than average number of ineligibles who live closer to their schools (Table 5). In addition to the transportation of ineligibles, differentials in the number of special students transported impact costs. Special student transportation incurs many more miles per student than regular transportation (Table 8). The higher proportion of special to regular transportation in the central city districts (Table 7) may contribute to the higher overall costs in these districts.

To examine the distribution of costs within district budgets, operational costs can be divided into four functional components: (1) office costs, which include all reported administrative and clerical costs, (2) bus drivers' salaries, which are the gross salaries paid to drivers for regular and special education transportation, (3) bus maintenance costs, which include maintenance salaries and materials and money paid for contracted maintenance, and (4) bus operating costs, which include gas and oil costs and bus insurance costs.

A detailed examination of the data again shows marked variability

TABLE 6. PER UNIT OPERATIONS COSTS OF PUPIL TRANSPORTATION BY COMMUNITY TYPE: 49 TEXAS SCHOOL DISTRICTS, 1972-1973

	Total Cost Per Student Transported Per Day[a] $	Total Cost Per Vehicle Mile[a] $	Total Vehicle Miles Per Student
Central City (over 100,000)	.30	.38	.77
Central City (below 100,000)	.28	.42	.66
Surban (Central County)	.24	.45	.53
Suburban (Non-central County)	.23	.29	.79
Urban Place	.42	.25	1.70
Rural	.37	.19	1.97

[a]Calculations assume 180 days in the school year, and include both regular and special transportation

TABLE 7. LOCAL COST DIFFERENTIALS: 49 TEXAS SCHOOL DISTRICTS, 1972-1973

	Average Gasoline Costs Per Gallon	Median District Bus Driver Salaries (Per Month)
Central City (over 100,000)	21.23	214
Central City (below 100,000)	17.58	170
Suburban (Central County)	21.55	186
Suburban (Non-central County)	18.98	134
Urban Place	19.26	144
Rural	18.85	134

TABLE 8. DIFFERENTIALS BETWEEN SPECIAL EDUCATION AND REGULAR TRANSPORTATION: 49 TEXAS SCHOOL DISTRICTS, 1972-1973

	Miles Per Student (Overall)	Miles Per Student (Regular)	Miles Per Student (Special)	% of Special to Total Students Transported
Central City (over 100,000)	.77	.44	3.27	11.77
Central City (below 100,000)	.66	.59	2.28	4.16
Suburban (Central County)	.53	.43	3.00	3.64
Suburban (Non-central County)	.79	.79	--	0.00
Urban Place	1.70	1.70	--	0.00
Rural	1.97	1.97	--	0.00

between school transportation systems. Examining the percent of total costs falling into each category, office costs range from 3.4% to 22.53% with a total sample percentage of 8.44%, bus drivers' salaries range from 27.52% to 66.40% with an average of 46.89%, and bus operating costs vary from 7.25% to 29.66% with an average of 15.30%. Some of this variability can be attributed to data deficiencies which were particularly severe with respect to component costs, but a hint as to more basic sources is again provided by an analysis based on the type of community served (Table 9).

A higher percentage of the total budget is expended upon bus operating costs in the suburban (non-central county), urban place and rural districts than in other community types. This occurs despite the lower per gallon gasoline costs in these areas (Table 7), and appears to reflect the greater number of miles driven per student transported in these places as against in the larger cities and their immediate suburbs. These latter areas expend a higher proportion of their budgets upon bus driver salaries. This appears to be a consequence of the higher monthly salary rates prevalent in major cities and their immediate suburbs (Table 7). The proportion of expenditures upon administrative costs are relatively consistent across community types. Although there is variability in maintenance costs, it cannot be clearly associated with any particular factor. Local decisions as regards preventive as against corrective maintenance programs and the age of the school bus fleet are likely influents. However, data were not available on these factors.

Since bus operating costs primarily comprise gasoline expenditures, it can be expected that in future years operating costs will comprise a higher proportion of the total budget. The data presented here pertain to the school year immediately preceding the oil crisis of winter, 1973-1974. It had a marked impact upon gasoline prices for school districts (Table 10). However, because it occurred in the middle of the school year, and districts differed as to their contractual supply arrangements and gasoline on hand, its full impact cannot be assessed until data for the 1974-1975 school year are available.

TABLE 9. THE DISTRIBUTION OF TRANSPORTATION OPERATIONS COSTS BY COMPONENTS: 49 TEXAS SCHOOL DISTRICTS, 1972-1973

	% Office Costs	% Bus Driver Salaries	% Maintenance Costs	% Bus Operating Costs
Central City (over 100,000)	7.43	50.24	28.00	14.33
Central City (below 100,000)	9.36	42.92	32.11	15.62
Suburban (Central County)	9.18	47.62	28.30	14.92
Suburban (Non-central County)	8.99	37.85	33.74	19.42
Urban Place	8.72	37.55	35.28	18.44
Rural	8.82	42.36	26.73	22.08

TABLE 10. COMPARISON OF GASOLINE PRICES FOR SCHOOL YEARS 1972-1973 AND 1973-1974 FOR SELECTED TEXAS SCHOOL DISTRICTS

District Name	72-73 Price (¢)	73-74 Sept. Price (¢)	73-74 May Price (¢)
Abilene	16.66	21.30	34.50
Alamo Heights	32.70	32.70	49.50
Albany	18.40	18.70	32.60
Amarillo	17.95	17.95	35.90
Andrews	18.55	25.90	38.90
Arlington	20.50	27.18	39.98
Canyon	18.50	20.00	36.00
Columbia-Brazoria	20.95	27.48	41.60
Dallas County	45.50	32.60	39.60
Deer Park	18.50	18.50	35.00
El Paso	17.70	25.20	35.70
Fort Stockton	21.09	21.09	21.09
Goliad	18.75	18.75	29.65
Henrietta	18.54	27.70	37.10
Hereford	17.95	17.95	34.60
Lubbock	17.95	23.00	38.50
Mesquite	22.90	25.10	37.30
Port Arthur	19.95	23.70	32.30
Rankin	19.22	26.50	34.00
Richardson	16.50	35.00	34.30
San Antonio	31.90	33.90	48.90
San Angelo	15.19	20.19	36.47
Spearman	19.00	24.00	32.90
Temple	17.90	17.90	34.50
Wall	18.90	24.20	39.50
Waxahachie	18.90	23.00	42.50
Ysleta	22.80	24.20	33.50

A PREDICTIVE MODEL FOR TRANSPORTATION COSTS

Model Format

There are many possible formulations for a model to predict transportation costs.[10] This study utilized a multiple regression framework, consequently decisions were necessary on the precise form of the dependent (criterion) and independent (predictor) variables. The dependent variable had to comprise a measure of the costs incurred by a school district in transporting students. This could be expressed in absolute cost terms for all students, or in a unit cost format in which costs are expressed per base unit, such as pupils, routes, buses, miles, etc. Total transport costs of a school district, expressed either in absolute or in per-unit terms could also be sub-divided into component cost categories such as maintenance, salary costs, etc., with each component being predicted separately. The predictor variables could comprise measures of the transportation system operated, the school district served by the system, or the community within which the district was located. Data from the detailed sample were utilized to explore most of these possibilities. It was concluded that, for the purpose of developing an allocation formula, the most appropriate model was one predicting per unit total transportation costs from density measures of the school district. In addition, regular transportation was separated from special student transportation.

One total cost model, rather than several component cost models, was chosen because parity of the various components between districts was hard to establish. Cost accounting methods made it extremely difficult to ascertain accurately expenditures for each component, and the distribution of the transportation dollar between different categories was often a local decision based upon trade-offs appropriate within a particular district.

Utilization of a per unit rather than absolute cost measure emphasizes the differential costs experienced by school districts per pupil transported. Much of the dissatisfaction with the current state allocation formula had

[10] J.H. Miller and J.C. Rea, "Comparison of Cost Models for Urban Transit," Highway Research Record, No. 435, 1973, pp. 11-19.

derived from its failure to incorporate these differentials. Measures of system magnitude, such as number of students transported and total miles travelled, were excellent predictors of total cost (2 > .90). However, these size factors dominated regression equations and excluded the impact of factors causing differential costs between districts. Furthermore, the large variability within the data vectors caused acute amplification of tendencies not accounted for by the form of the regression equation. Thus, the predicted cost for a specific school district could be way out of line with actual costs incurred.

The choice of densities as appropriate predictors for transportation cost was based upon the analysis discussed in the previous section. Densities provide an overall indication of the spatial distribution of students within a school district (pupil areal density), or along transportation routes (linear density.)[11] These distributions have a marked impact upon the distances which must be covered to collect students and hence upon the overall transportation costs. Secondly, areal densities provide an objective indication of the nature of the community within which the school district is located. High densities typify larger cities, medium densities suggest suburbs and smaller towns, and low densities indicate rural areas (Table 5). The type of community served was shown to impact transportation costs because of variation in salaries and other local cost components. Thirdly, densities can be calculated from data which are readily obtainable from school districts.

Finally, it should be emphasized that the predictive model as developed applies only to regular student transportation. Initial model exploration used cost figures which combined both regular and special education transportation. However, the per pupil cost of special education transportation is considerably higher than for regular pupils. It was felt that the former could be more appropriately handled in a separate model.

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[11]Linear Density (LD) is the number of pupils transported daily divided by the total route miles of the transportation system.

Correlation Between Variables

To finalize the predictive model, data from the expanded sample of school districts were used. Several conclusions can be drawn from the correlations between the variables collected in this sample (Table 11). First, there are high positive correlations between total transportation costs and the number of pupils transported and total miles driven (r = .95 and .93, respectively.) This illustrates the predominance of size as the factor determining transportation system costs. Also, pupils and miles are themselves highly correlated, suggesting that increases in students transported can only be achieved by increasing the number of buses and/or miles driven, rather than by increasing bus sizes. The negative correlations between transportation costs per pupil and the number of pupils transported (r = -.29) and the number of miles driven (r = -.18) indicate the possible existence of scale economies with respect to pupils transported and miles driven. A final point to note are the fairly high correlations between unit costs and linear density (LD). The negative correlation with costs per pupil suggests that as linear density increases fewer miles are run for each student transported and costs per pupil are thus reduced. The positive correlation with costs per mile suggests that as linear densities increase the higher load factors and increased stop and go driving force costs-per-mile up.

Variable Selection and Model Calibration

Cost per pupil transported was selected as the criterion variable. School districts were then divided into six groups on the basis of their pupil areal density (PAD). Within each group estimating equations involving three possible predictor variables - pupils transported daily, linear density, and transported pupil areal density were explored.[12] A final equation utilizing only linear density as the predictor variable was selected.

Segmentation of the districts into groups on the basis of PAD was undertaken for several reasons. Segmentation emphasized the model's

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[12] Transported Pupil Areal Density (TPAD) is the number of pupils transported daily divided by the area of the school district in square miles.

TABLE 11. CORRELATION MATRIX FOR VARIABLES IN THE EXPANDED SAMPLE

Variable Name	Cost/ Pupil	Cost/ Mile	PUPILS	Miles	Linear Density	PAD	Total Cost
Cost/Pupil	1.000	-.188	-.285	-.175	-.522	-.193	-.189
Cost/Mile		1.000	.306	.108	.697	.475	.347
PUPILS			1.000	.913	.387	.499	.945
Miles				1.000	.140	.318	.933
Linear Density					1.000	.507	.277
PAD						1.000	.442
Total Cost							1.000

attempt to incorporate differences between school districts in their transportation situation. Failure to achieve this had been a constant source of criticism of the current formula used to allocate state monies to local districts. PAD was the most appropriate variable to differentiate districts since it indexes the spatial distribution of students in the district, as well as cost differentials (such as salary levels) associated with the type of community within which the district is located. Analysis of the detailed sample suggested that both of these impact transportation costs.

Automatic Interaction Detection (AID) analysis was utilized to segment the PAD variable so that each segment would contain school districts with a similar transportation cost situation. Since linear density was the primary predictor variable for transportation costs, PAD was segmented so that each division contained districts as similar as possible with respect to this variable. The AID analysis yielded six statistically significant groupings which are shown in Figure 1.

Plots of the predictor variables against cost per pupil indicated non-linear relationships. Consequently, two predictive models were examined for each segment:

$$\ln C/P = a_0 + a_1 \ln LD + a_2 \ln PUPILS + a_3 \ln TPAD \qquad (1)$$

and

$$\ln C/P = a_0 + a_1 + a_2 LD + a_3 PUPILS + a_3 TPAD \qquad (2)$$

where

C/P = cost per pupil per annum (total operations cost divided by PUPILS)

LD = linear density (PUPILS divided by the total route miles of the transit system)

PUPILS = pupils transported daily

TPAD = transported pupil areal density (PUPILS divided by area of school district in square miles)

a_i = regression coefficients

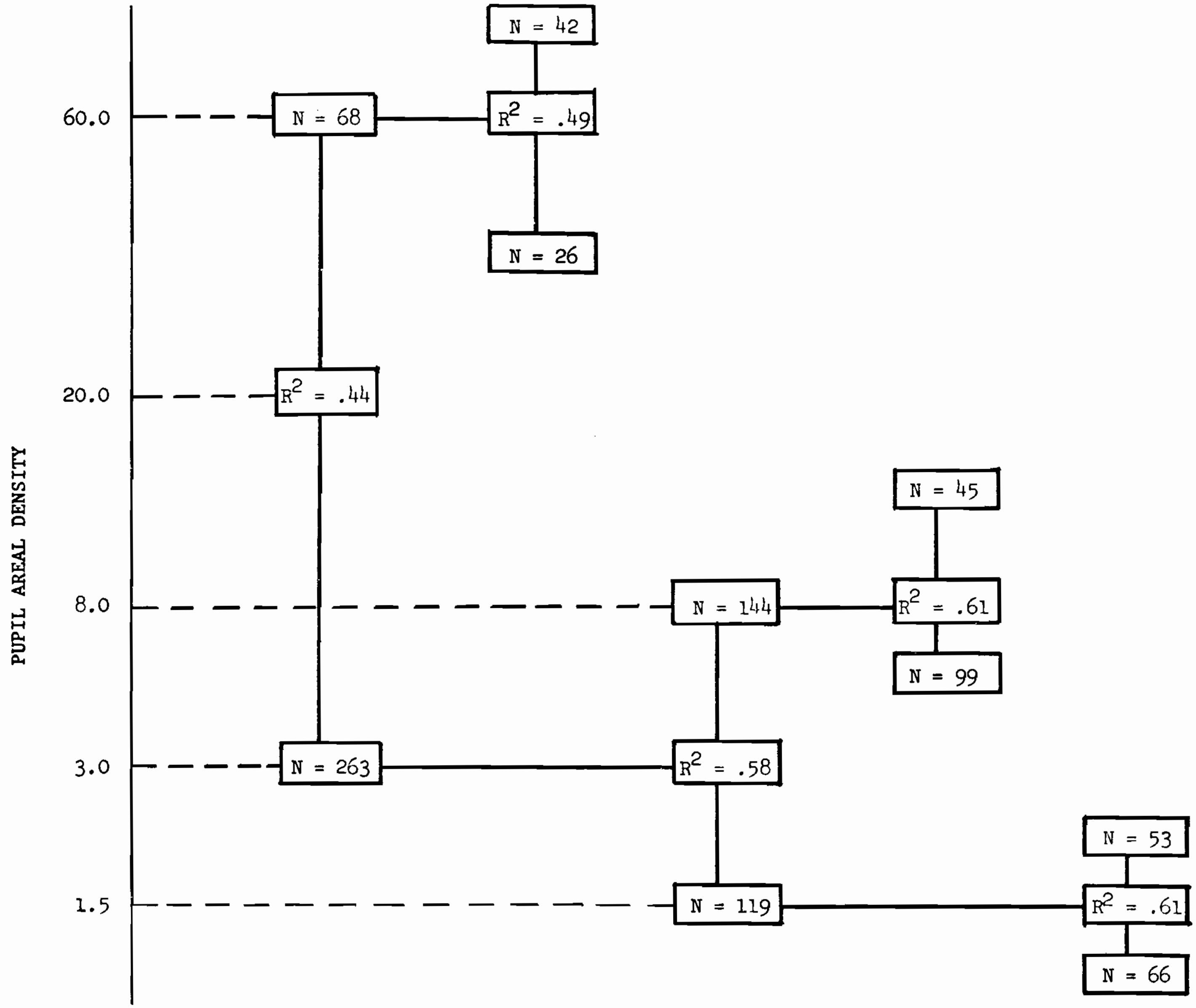

FIGURE 1. SEGMENTATION OF PAD BASED UPON LINEAR DENSITY

When linear density (LD) was in the equation the contribution of transported pupil areal density (TPAD) was insignificant in all segments. Segmentation on pupil areal density (PAD) and prediction with linear density apparently accounted for all of the information transported pupil areal density could provide, and it was dropped from the equation. Pupils transported daily (PUPILS) was statistically significant in all cases, but its maximum contribution of 0.016 to R^2 added little to predictive ability, thus it was omitted.

An analysis of the residuals and R^2 values showed that Equation 1 possessed higher predictive ability than Equation 2. Consequently, an equation of the form:

$$C/P = a\ LD^b$$

was the most appropriate for predicting maintenance and operations costs of regular student transportation. The predictive equations for each of the six segments are given in Table 12. Although the R^2 values are not extremely high, the model, given its simplicity, is relatively successful in predicting total operations costs incurred by districts.[13] As a percentage of the sum of actual district costs for each PAD group, the sum of absolute errors of predicted from actual costs is generally less than 24%, with an overall state figure of 20%.

CONCLUSIONS AND IMPLICATIONS

Rural Public Transit

Recently, transportation problems in rural areas have received increasing attention.[14] This has been motivated both by the energy crisis as well as a realization of the transportation needs of those unable to

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[13]Total costs are derived by multiplying costs per pupil by the number of pupils transported.

[14]For instance, section 147 of the Federal Highway Aid Act of 1973 makes provision for a Rural Highway Public Transportation Demonstration Program.

TABLE 12. PAD GROUPS AND THEIR COST FORMULAE

Group No.	PAD Range	Formula Equation	R^2	Sample N	State N
1	0 - 1.5	$C/P = 48.2LD^{-.7649}$	0.5483	66	241
2	1.5 - 3.0	$C/P = 49.4LD^{-.7369}$	0.5716	53	180
3	3.0 - 8.0	$C/P = 53.3LD^{-.5801}$	0.5457	99	309
4	8.0 - 20.0	$C/P = 51.2LD^{-.7532}$	0.5314	45	131
5	20.0 - 60.0	$C/P = 66.5LD^{-.8505}$	0.3898	26	84
6	60.0 and above	$C/P = 71.1LD^{-.7405}$	0.5696	42	93

Note: Parameters in this table provide estimates of cost per pupil per annum.

utilize automobiles.[15] Unfortunately, little is known about the costs of operating public transit in these areas since traditionally they have relied solely upon the automobile. Because pupil transportation differs considerably from public transit in its system characteristics, absolute cost figures for pupil transportation in rural areas are an unreliable indicant of likely public transit costs. However, cost comparisons for pupil transportation between rural and urban areas provides some indication of the likely costs involved in rural as against urban public transit.

It is often felt that the per capita cost of rural and small town transportation greatly exceeds that of urban transit because of larger distances and lower population densities. The conclusion to be drawn from the data in this study is that the cost differential may not be as large as might be expected. Although there are very marked differences in the density of the target population (Table 5), differentials in miles per student transported (Table 6) are far lower, and differentials in operational costs per student transported are even less (Table 6). For instance, operational costs in rural areas are only 23% higher than in central cities. Particularly surprising is the lower cost per student in suburban areas as against central cities. However, these figures must be viewed in light of the much lower salaries prevalent in rural as against urban areas. Equalization of salary scales would have a marked impact upon these relative figures since salaries constitute the major portion of operational costs.

Models of Transit Systems

On initial evaluation, the model developed in this paper does not appear to compare favorably with other models for predicting transit costs.[16] Many of these have achieved explained variances (R^2) exceeding 99%, in contrast to values of 50% here. However, other models differ on two main grounds. First, they generally predict total costs rather than cost per

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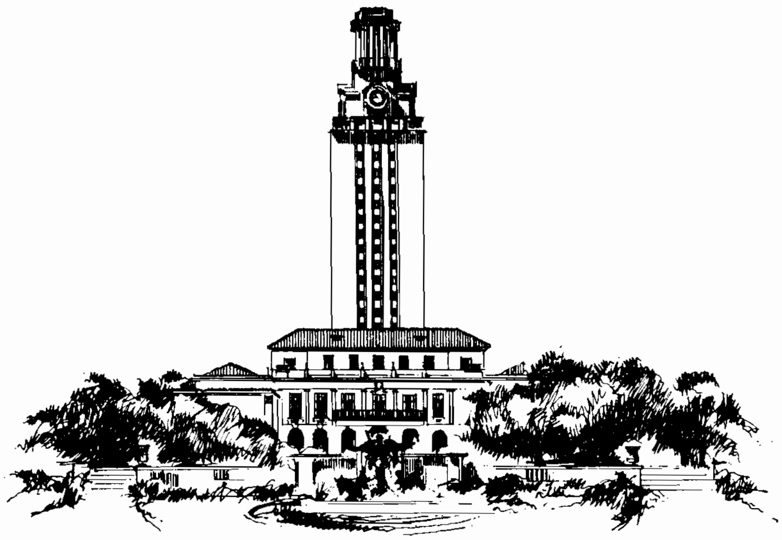
[15] Jon E. Burkhardt, The Transportation Needs of the Rural Poor, Bethesda, Md: Resource Management Corporation, July 1969.

[16] Miller and Rea, loc. cit.

passenger (pupil). Secondly, they utilize predictor variables which are measures of the characteristics of the transit systems, such as number of vehicles, vehicle miles or hours of service, and number of seats, passengers carried or passenger revenue. Experimentation in a similar framework with the detailed sample achieved similar results in this study. Utilizing total cost as a dependent variable, and inputting any predictor variable related to system size (such as pupils transported, miles driven, or buses operated) immediately gave very high R^2 values. However, this was a simple consequence of variability in the size of the transit systems considered.

Ultimately, the model developed here was to be incorporated into a formula for the assignment of state monies to local districts for student transportation. Emphasis was upon differentials in the per pupil cost of providing transportation. Because of the large number of districts in the state, together with the marked variability in local conditions, it was also desirable that local districts have maximum flexibility in designing systems to meet their own particular needs. Consequently, a model was sought which would predict variability in transportation costs per pupil from independent variables which were not transportation system specific. Furthermore, because the allocation formula and the model upon which it was based would require approval through the political process, simplicity was also a desirable characteristic. Within this framework the model is quite successful. By utilizing segmentation based on pupil density, and costs per student transported, it emphasizes cost differentials. It has a single independent variable which requires no specification of transportation system characteristics other than total route mileage and number of students transported. Given these characteristics the model accounts for more than fifty percent of variability in transportation costs per student, and an average of 80% of total transportation costs.



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