Projecting Automobile Availability by Urbanized Area

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This paper is made up of extractions from an unpublished technical report on research conducted in one task under the Bureau of Public Roads national research project, "Underlying Factors in Urban Transportation Analysis." The task is concerned with improving the techniques of estimating future potential demand for highways. The most important single indicator of demand for highway transportation is automobile availability (measured by the ratio of automobiles available to employed residents). Multiple regression analyses were made of the relationships between the 1950 and 1960 ratios of percent shares of automobiles available and nine related population, employment, and income variables for 198 urbanized areas.

Tests were made of the accuracy of the equations in predicting 1960 automobiles available using 1950 as the base year. The equation for urbanized areas in the Type A category, although not as accurate as most of the other equations, predicted values that are within ± 15 percent of the actual values in approximately two-thirds of the cases. Projections of the number of automobiles available in 1975 and 1990 were made for the 28 urbanized areas classified as Type A.

•THIS paper presents part of the research procedure, data development, and statistical analyses and testing that went into the development of quantitative measures of the relationships between change in an urban area's level of automobile availability and changes in a few key related variables. Such measurements might provide better understanding of the different trends among urban areas in the extent to which certain transportation facilities are used and might also serve as guidelines in forecasting future levels of automobile availability, and the implied transportation requirements for an urban area. (The term "urban area" is commonly thought of as being composed of a city and its surrounding "built-up" suburbs; however, delineations of any one urban area may vary from study to study. In this study "urban area" conforms to the definition of "urbanized area" as defined by the U. S. Bureau of the Census in 1960 and given under the section on data development that follows later.)

The aim was to devise a simplifed, rapid, inexpensive, and adequate method of estimating future potential demand for highways by urban area. This was to be accomplished with the use of available data from usual government sources. Another purpose was to tie urban area forecasts to those at the national and state levels.

AUTOMOBILE AVAILABILITY—A KEY PLANNING FACTOR

The most important single indicator of demand for highways is automobile availability. Estimates of the number of automobiles currently available and likely to be available in the future indicate the trend in travel that parallels the change in automobiles available and, consequently, the future requirements of highway and parking facilities implied in these trends.

Future automobile availability may be considered not only as a basis for judging the future demand for highway and parking facilities, but also as an indicator of their

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potential impact on the environmental quality of an urban area. In some cases, problems of traffic congestion, noise and fumes, and the proliferation of highway-oriented businesses may be implied in forecasts of higher levels of automobile availability.

PROCEDURE

Decision Variables—Demographic, Social, and Economic

Hypothetically, change in the aggregate number of automobiles available is associated with change in the area's demographic, social, and economic characteristics. The demographic characteristics are the number of inhabitants in the total area and their distribution between the central city and urban fringe. The total number of families and their distribution among low-, medium-, and high-income brackets are considered to be key social factors. Critical economic factors are aggregate family income and the total number of employed area residents. These factors, selected to be the variables in multiple regression analyses, are listed below:

X_1 = Automobiles available — Dependent or criterion variable

Independent or decision variables:

X_2 = Total population
X_3 = Central city population
X_4 = Urban fringe population
X_5 = Low-income families
X_6 = High-income families
X_7 = Middle-income families
X_8 = Number of families
X_9 = Aggregate family income
X_{10} = Employed residents

Selection of these variables is based on a general theory of growth in urban automobile availability. According to this theory, the number of automobiles available will increase with an increase in an area's total population and/or population shifts from the central city to the suburbs. These population changes reflect change in the distribution of income among the families in the area and/or change in the level of aggregate income. Change in the level of employment is a prime factor underlying change in income. While this deductive logic seems reasonable in general, hypothetically, the relative importance of the associated factors would vary from one area type to another. One or more of the independent variables would be significant in one type of area but not in others. It is also recognized that there is the element of time in the relationships between these factors so that some changes will lead, be concurrent with, or lag other changes. Lead-lag analyses, however, are beyond the scope of this report.

Growth Relationships Vary With Rate of Automobile Availability

Theoretically, the relationship between increasing rates of automobile availability and economic growth is largely determined by the rate of automobile availability already attained. An area with a high ratio of automobiles available to persons employed can be expected to raise that rate only gradually, whereas the opposite would be true of an area with a relatively low existing rate of automobile availability. This would be true even though both areas experienced similar rates of general economic growth. In areas with relatively moderate rates of automobile availability, the increases in these rates would be similar to the economic growth rates.

An Urban Typology Based on an Automobile Availability Index

An urban typology based on the automobile availability rate as a transportation criterion was devised to facilitate urban area comparisons and thereby help to isolate the factors associated with urban area variations in transportation utilization. In a previous study, the authors classified the 213 urbanized areas that existed in 1960, using an index of automobile availablility as the classification criterion (1). The ratio of the number of automobiles available per 100 employed residents was used as the index of automobile availability. The automobile availability types, the automobile availability index ranges for each type, and the number of urbanized areas that fall into each category are as follows:

Type	Number of Autos per 100 Employed Residents	Number of Urbanized Areas
A	100 or more	28
B	90 to 100	31
C	80 to 90	62
D	70 to 80	61
E	60 to 70	15
F	Under 60	1

Because the automobile is the predominant mode of person transportation in almost all urban areas, the ratio of automobiles available to the number of residents employed serves to differentiate between urban areas having varying degrees of automobile preponderance. As noted in the previous study, this measure also helps to indicate the degree of reliance placed on the automobile by workers in their work trips (1). This classification satisfied the need to overcome, to some extent, the variation in rates of automobile availability among urban areas. It was anticipated that analyses of the areas by automobile availability class would help isolate the key variables related to change in automobile availability in each type of area. Prior study (1) indicated the existence of some correlation between an urban area's transportation characteristics and the region of the country in which it is located. Figure 1 shows the national distribution of urbanized area types with populations in excess of 150,000. A southwest to northeast

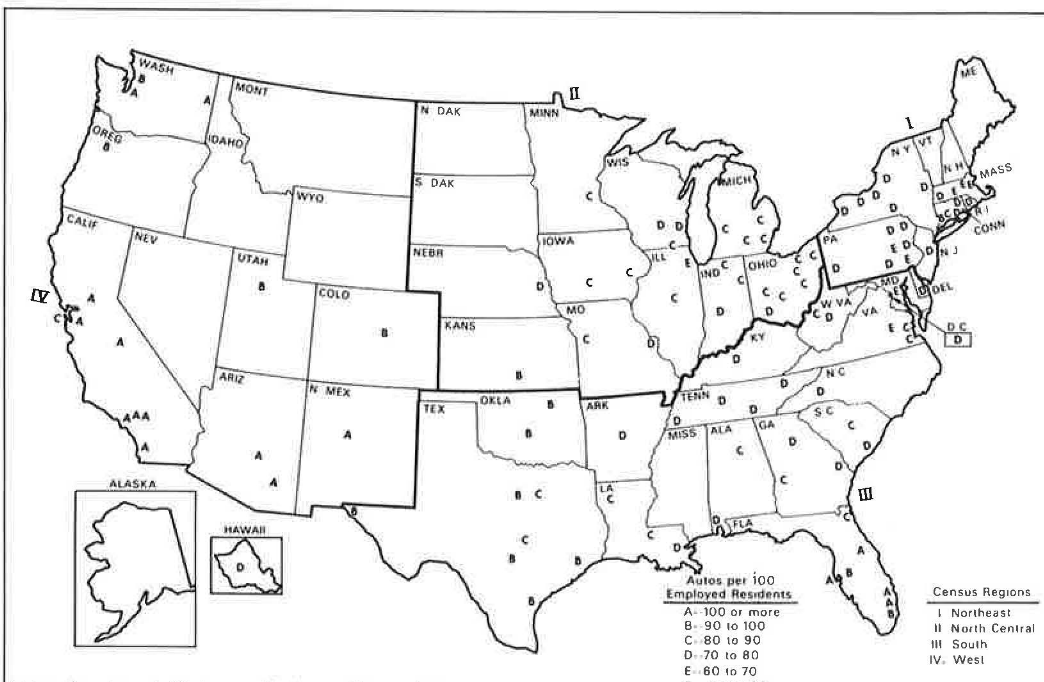

Figure 1. Geographic distribution of urbanized area types with over 150,000 population.

pattern of high (A) to low (E) types is fairly distinguishable. The areas were therefore grouped according to census region for analysis. This general approach seems to be in keeping with Coleman Woodbury's suggestion (2, p. 12) that ". . . comparative studies of many areas or groups of areas may be the road to some explanations that no consideration of the aggregates alone or of individual areas could reveal. . . ."

In his study of intracity traffic movements, F. Houston Wynn (3) observed, "Much serious work has been done by persons seeking solutions to specific problems or making intensive study of a particular urban community. Few researchers have attempted to discover the characteristics of urban travel that are common to all communities."

DATA DEVELOPMENT

Area Definition

Urbanized or urban area is the geographic unit with which this study is concerned. It is defined by the U.S. Bureau of the Census and contains one or more central cities with a population of 50,000 and an urban fringe. In developing data for some variables and certain areas, however, it was necessary to base estimates on data for other geographic units, such as standard metropolitan statistical area (SMSA), state economic area (SEA), and county. Instances in which this was done are explained in the "Data Sources" section discussed later.

Urbanized Area Classifications

Data were compiled for the areas in each of five automobile availability classes developed in an earlier study, ranked as of 1960. The urbanized areas were also separated into four groups according to the census regions in which they were located. When an area is located in more than one region, it is classified in the region in which the largest proportion of the area's population is located.

Data Sources

Most of the data used in the empirical phase of this study comes from Census Bureau publications. However, for a considerable number of the 213 urbanized areas in 1960, there were no readily available comparable data for 1950. In such cases estimates were made using 1950 county data. For the New England region, data for state economic areas containing standard metropolitan statistical areas were used as surrogates for urbanized area data.

Not only were there serious problems of comparability in area of definitions, but there were also problems of comparability between 1950 and 1960 in definitions of some of the variables used. The following is a list of data sources for the variables used in this study. Where appropriate, notes have been inserted to explain means used to overcome in part some of these problems of definition and data comparability:

X_1 = Automobiles available

1960—Estimates based on the number of occupied housing units with one, two, and three or more automobiles available as reported in the U.S. Census of Housing: 1960, Vol. 1, State and Small Areas, HC(1), Tables 16 and 30.

1950—Automobile registrations as of July 1, 1947, as reported in the County and City Data Book, 1949, Table 2 (for Standard Metropolitan Statistical Areas) and Table 3 (for counties), column 32 (Records of R. L. Polk and Company, compiled from state motor-vehicle registrations).

Assumptions: Because the absolute data would be converted to percentage distribution, it was assumed that the distribution of SMSA shares would not be significantly different from the distribution of urbanized area shares. It was also assumed that between 1947 and 1950 there was no change in urbanized area shares of automobile registrations. Another assumption is that there is no significant difference between percentage distributions of automobiles available and automobile registrations.

X_2 = Total population
X_3 = Central city population
X_4 = Urban fringe population

1960 and 1950—U.S. Census of Population: 1960, "Number of Inhabitants, United States Summary," PC(1) 1A, U.S. Bureau of the Census, Table 22, p. 40, and Table 30.

Note: 1950 population data were not available for some areas. In these cases the county urban population was used for the total urbanized area population and urban place population was used for central city population.

X_5 = Low-income families
X_6 = High-income families
X_7 = Middle-income families
X_8 = Number of families
X_9 = Aggregate family income
X_{10} = Employed residents

1960—U.S. Census of Population: 1960, "General Social and Economic Characteristics," PC(1), state series, Tables 75, 76, 85, and 86. Compiled from County and City Data Book, 1962, Table 4, columns 217, 219, and 220.

1950—U.S. Census of Population: 1950, Vol. 2, "Characteristics of the Population," part for each state, Tables 35, 37, 43, and 45, and County and City Data Book, 1952.

Note: Low-income families are those with incomes under $2,000 in 1950 and under $3,000 in 1960. High-income families had incomes of $5,000 or more in 1950 and $10,000 or more in 1960.

For a considerable number of areas, 1950 data are not available. In such cases, estimates for the urbanized area were based on the central city percent distribution of families by income class (County and City Data Book, 1952, Tables 3 and 4).

Aggregate family income was obtained by multiply the number of families by the median family income.

Shift-Share Approach

Many of the problems of data comparability were largely overcome through use of a shift-share approach to the empirical analysis. Data for 1950 and 1960 were compiled in absolute terms for the urbanized areas in each of five transportation classes and four census regions.

The amount attributable to each urbanized area was then expressed as a percent share of the class or regional total in which it was classified. The ratios of the 1960 shares to those of 1950 became the basic measures used in this analysis. This, then, became an analysis of relatives, with the ratios of the 1960 to 1950 shares providing a cross section of change in the 10 variables for each urbanized area, relative to the cross section of change for the other urbanized areas of the same type or region.

Use of percent shares made it possible to compare the values of certain variables in 1960 to their 1950 values, although the definitions of the variables differ somewhat between the two years. The number of automobiles registered in 1950, for example, is not comparable to the number of automobiles available in 1960. By assuming uniformity among the urbanized areas in the difference between the two, the percent shares in 1950 and 1960 became comparable.

Use of percent shares also made it possible to use data for standard metropolitan statistical areas as surrogates for urbanized area data. It was assumed that the percent distributions would not differ significantly.

Estimated percent shares for a group of urbanized areas are applied to a total amount for the entire group to get estimates in absolute amounts for each urbanized area. Estimates of the future total number of automobiles available for the groups of urbanized areas are made on the basis of growth rates implied in forecasts of statewide automobile registrations prepared by state highway departments, as will be shown later.

Multiple Regression Analyses

The multiple regression method was used to analyze relationships between the 1960 to 1950 change in automobile availability (the dependent variable) and change in income, employment, and population (the independent variables as listed previously). Regression analyses were also made using population, employment, and income variables alternately as dependent variables. Due to problems of comparability for the two years, several areas were combined. The New York-Northeastern New Jersey area was excluded because it was the only one in Type F. Output from these regression analyses included equations for predicting the ratio of change in shares of automobiles available in urbanized areas of each transportation type and census region; measures of predictability and reliability such as the standard error of estimate, the multiple regression coefficient, and the coefficient of multiple determination; and forecasts to 1975 and 1990 of the number of automobiles available in 28 Type A urbanized areas.

RESULTS

Nine Regression Models

Multiple regression analyses of the growth data for one dependent variable and nine independent variables produced nine model equations; one for the urbanized areas in each of five transportation classes, and one for the areas in each of four census regions. Table 1 lists these equations along with measures of their accuracy in estimating future growth rates for typical urbanized areas, and for those in a certain section of the country. Differences in the construction of these equations are readily apparent.

Although nine independent variables were used, not more than two emerged from any one analysis as being significantly related to change in automobile availability. This result is due partly to the requirement of a 5 percent minimum F level in order for the independent variable to enter. If, after entry, the F value fell below the 5 percent level of significance, that independent variable was removed from the equation. This procedure is in keeping with the objective of developing simple equations with a minimum of critical variables. In the cases of equations for Type A and E areas, this minimum is one independent variable.

Of the nine independent variables analyzed, only two—low-income families (X_5) and middle-income families (X_7)—do not appear in any of the nine equations. High-income families—the other indicator of income distribution—appears once as the determining factor in Type E areas.

Type A Areas Analyzed

Regression analysis of the 1960 to 1950 ratios of the percent-share distribution of the variables among urbanized areas classified as Type A resulted in the following equation

$$X_1 - 0.2884 + 0.83404X_2$$

TABLE 1

REGRESSION MODELS FOR USE IN FORECASTING AUTOMOBILES AVAILABLE BY URBANIZED AREAS IN FIVE TRANSPORTATION TYPES AND FOUR REGIONS

Urbanized Area	No. of Areas	Constant	First Independent Variable	Second Independent Variable	Standard Error	Correlation Coefficients	
						R	R^2
Type A	28	0.28840	$0.83404X_2$	—	0.2253	0.863	0.7442
Type B	31	-0.19019	$0.65567X_3$	$0.56771X_8$	0.1346	0.901	0.8124
Type C	62	0.22008	$0.52842X_8$	$0.26688X_3$	0.1442	0.905	0.8185
Type D	61	0.55390	$0.81037X_3$	$0.77624X_8$	0.3490	0.993	0.9852
Type E	15	0.41353	$0.65262X_6$	—	0.1153	0.728	0.5297
Region I (Northeast)	34	0.53545	$0.53379X_{10}$	$-0.08414X_4$	0.0718	0.483	0.2333
Region II (North Central)	58	0.42003	$0.39640X_9$	$0.16364X_3$	0.0755	0.592	0.3508
Region III (South)	77	0.32562	$0.48945X_2$	$0.19741X_3$	0.2482	0.756	0.5724
Region IV (West)	28	0.47987	$0.78820X_9$	$-0.13670X_4$	0.2407	0.779	0.6062

in which X_1 equals the predicted ratio of the percent share of automobiles available and X_2 equals the ratio of the percent share of total population. This equation is shown as Part A at the top of Table 2. Part B of the same table gives the standard error of estimate ($S_{1.2}$), the multiple correlation coefficient ($R_{1.2}$), the coefficient of multiple determination ($R^2_{1.2}$), and other measures.

It is significant that, of the nine independent variables analyzed, only total population, in passing the F test at the 95 percent confidence level, emerged as an explanatory variable. One reason for this outcome may be that intercorrelations among the independent variables are high enough, in this case, so that none of the eight remaining variables could significantly add to the explanatory power of the total population variable.

It is likely, however, that the similarity of urbanized areas of this type, in their dependence on the automobile for transportation, is chiefly responsible for the close association between automobile and population growth rates. Persons migrating into these areas and residents of these areas who come of driving age have great need for automobiles because of the distances between locations of residence, occupation, recreation, and other centers of activity and, therefore, these persons are likely to buy automobiles with a minimum of regard for income and/or employment.

Stated differently, the characteristic spread-city, low-density structure of the urbanized areas in the highest automobile availability class is conducive to automobile

TABLE 2

TYPE A—PREDICTED AUTOMOBILES AVAILABLE

A. Estimating equation: $X_1 = 0.28640 + 0.83404(X_2)$. $S_{b_{1.2}} = 0.09352$.

B. $R^2_{1.2} = 0.7442$; $R_{1.2} = 0.863$; $S_{1.2} = 0.2253$; $\overline{X}_1 = 1.2377$. $S_{1.2} + \overline{X}_1 = 18$ percent. N = 28.

C. Automobiles available in 1960—predicted vs actual.

Urbanized Area	1950 Percent of Total	Predicted Ratio[a]	1960 Automobiles Available: Percent of Total[b]	1960 Automobiles Available: Predicted[c]	1960 Automobiles Available: Actual	Difference from Actual: Number	Difference from Actual: Percent
	(1)	(2)	(3)	(4)	(5)	(6)	(7)
Los Angeles-Long Beach, Calif.	61.6734	1.04179	56.9830	2,754,815	2,572,209	182,606	7.1
San Diego, Calif.	5.1438	1.18475	5.4048	261,293	295,916	-34,623	-11.7
San Jose, Calif.	3.5689	1.87425	5.9324	286,800	232,188	54,612	23.5
Phoenix, Ariz.	2.8496	1.47441	3.7263	180,147	203,742	-23,595	-11.6
Sacramento, Calif.	2.9483	1.27900	3.3444	161,684	174,733	-13,049	- 7.5
San Bernardino-Riverside, Calif.	2.6923	1.03804	2.4786	119,827	143,182	-23,355	-16.3
St. Petersburg, Fla.	1.8455	1.27800	2.0917	101,123	125,609	-24,486	-19.5
Fort Lauderdale-Hollywood, Fla.	0.9758	2.57944	2.2323	107,920	126,470	-18,550	-14.7
Albuquerque, N.M.	0.9562	1.29142	1.0952	52,947	83,258	-30,311	-36.4
Tucson, Ariz.	1.0859	1.63622	1.5758	76,182	82,585	- 6,403	- 7.8
Spokane, Wash.	1.9857	0.88666	1.5615	75,490	80,469	- 4,979	- 6.2
Tacoma, Wash.	1.9763	0.88308	1.5478	74,828	73,555	1,273	1.7
Fresno, Calif.	2.0320	1.04730	1.8874	91,246	79,335	11,911	15.0
Orlando, Fla.	0.9967	1.56382	1.3824	66,832	73,162	- 6,330	- 8.7
West Palm Beach, Fla.	1.0956	1.21336	1.1790	56,998	65,694	- 8,696	-13.2
Bakersfield, Calif.	1.3643	0.77332	0.9357	45,236	53,765	- 8,529	-15.9
Amarillo, Texas	0.8247	1.14855	0.8401	40,614	51,144	-10,530	-20.6
Wichita Falls, Texas	0.7581	0.87774	0.5901	28,528	34,887	- 6,359	-18.2
Colorado Springs, Colo.	0.7025	1.14163	0.7113	34,388	39,070	- 4,682	-12.0
Eugene, Ore.	0.8177	1.17216	0.8501	41,098	35,710	5,388	15.1
Abilene, Texas	0.7344	1.21961	0.7944	38,405	34,413	3,992	11.6
Odessa, Texas	0.3936	1.61295	0.5631	27,223	32,571	- 5,348	-16.4
Santa Barbara, Calif.	0.6168	0.81802	0.4475	21,634	30,369	- 8,735	-28.8
Midland, Texas	0.2230	1.63997	0.3243	15,678	24,842	- 9,164	-36.9
Lawton, Okla.	0.3573	1.11627	0.3537	17,100	19,757	- 2,657	-13.4
Billings, Mont.	0.4545	1.08191	0.4361	21,083	23,001	- 1,918	- 8.3
San Angelo, Texas	0.4731	0.81218	0.3407	16,471	21,590	- 5,119	-23.7
Great Falls, Mont.	0.4538	0.97032	0.3905	18,879	21,243	- 2,364	-11.1

[a]Ratio of the 1960 share to the 1950 share, as predicted by the estimating equation.
[b]Column 1 times column 2; results adjusted to add to 100 percent.
[c]Number of automobiles obtained by applying the percents in column 3 to the actual total of automobiles available—4,834,469. "Actual" refers to observed data.

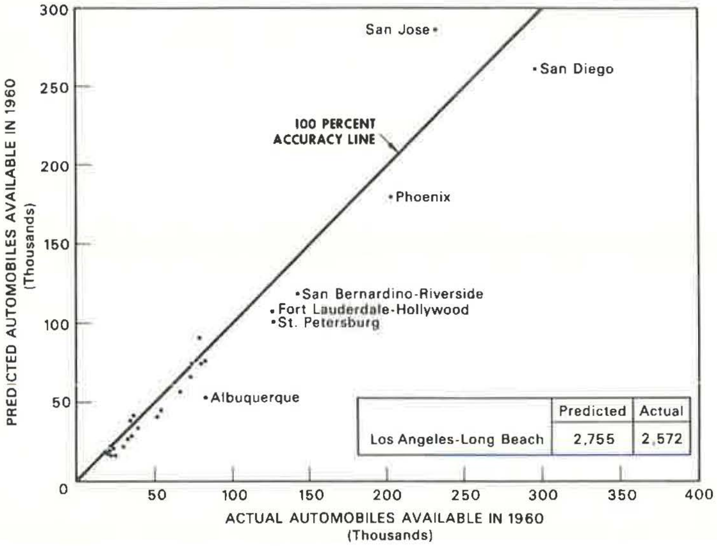

Figure 2. Predicted vs actual 1960 automobiles available in Type A areas.

travel, and the acceptance of automobile dominance by the residents virtually compels consumers in those areas to buy an automobile of any description at the earliest opportunity. With this in mind, it is reasonable to expect a Type A urbanized area to increase its share of automobiles at a rate that would be similar to the rate at which it raised its share of the population in all Type A areas. The coefficient of multiple determination ($R^2_{1.2}$) of 0.7442 means that among Type A urbanized areas 74 percent of the variation in the rates of increase in automobile shares is explained by the population shares. The standard error of estimate ($S_{1.2}$) of 0.2253 indicates that approximately 68 percent of the estimates of change in automobile shares produced by this equation would fall within the rather wide range of ± 0.2253 about the regression line.

Predictive Accuracy of Equation for Type A Areas

Part C of Table 2 gives results of tests in which the equation was used to predict the 1960 to 1950 ratios of automobile shares (column 2) based on recorded rates of change in population shares over the same 10-year period. The estimated growth rates are applied to the 1950 percent distribution to get the estimated 1960 percent distribution. The estimated total number of automobiles available in all Type A areas in 1960 is distributed among the areas on the predicted 1960 percent distribution. Differences between predicted and observed, or recorded data in the last two columns show that the equation generally underpredicts. All but 6 of the 28 urbanized area predictions are on the low side (Fig. 2).

It appears that one or more key underlying variables that might explain much of the 26 percent unexplained variance have been omitted from the analysis. Change in the age distribution of the population might be one factor. An above-average increase in the proportion of the population in the driving-age bracket would probably cause an equation using change in total population as the independent variable to underestimate automobile availability. The reverse, an overestimate of automobile availability, would be probable for an area with a declining proportion of its population in the driving-age group.

Projecting Forecasts to 1975 and 1990

Table 3 demonstrates the step-by-step method of projecting the number of automobiles available in the 28 Type A urbanized areas in 1975. Forecasts of the independent variable and total population had been prepared (in unpublished data) by Stanley Bielak

TABLE 3

PREDICTED AUTOMOBILES AVAILABLE IN TYPE A AREAS FOR 1975

Urbanized Area	Population					Automobiles Available			
	1975		Percent of Total, 1960	Ratio of Percent Shares, 1975-1960	Column 4 Times 0.83404[b]	Ratio of Percent Shares, 1975-1960[c]	Percent of Total		Forecast for 1975[e]
	Number[a] (thousands)	Percent of Total					1960	1975[d]	
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
Los Angeles-Long Beach, Calif.	9, 156	46.3173	50.3742	0.9194	0.76690	1.0553	56.9830	53.6877	4, 671, 903
San Diego, Calif.	1, 590	8.0433	6.4910	1.2391	1.03346	1.3219	5.4048	6.3787	555, 074
San Jose, Calif.	931	4.7096	4.6798	1.0064	0.83938	1.1278	5.9324	5.9734	519, 805
Phoenix, Ariz.	1, 111	5.6202	4.2854	1.3115	1.09384	1.3822	3.7263	4.5984	400, 153
Sacramento, Calif.	783	3.9609	3.5083	1.1290	0.94163	1.2300	3.3444	3.6726	319, 590
San Bernardino-Riverside, Calif.	569	2.8784	2.9307	0.9822	0.81919	1.1076	2.4786	2.4510	213, 286
St. Petersburg, Fla.	580	2.9340	4.8638	0.6032	0.50309	0.7915	2.0917	1.4781	128, 624
Fort Lauderdale-Hollywood, Fla.	631	3.1920	2.4835	1.2853	1.07199	1.3604	2.2323	2.7112	235, 929
Albuquerque, N.M.	442	2.2359	1.8725	1.1941	0.99593	1.2843	1.0952	1.2558	109, 280
Tucson, Ariz.	573	2.8986	1.7654	1.6419	1.36941	1.6578	1.5758	2.3323	202, 957
Spokane, Wash.	327	1.6542	1.7615	0.9391	0.78325	1.0716	1.5615	1.4939	129, 999
Tacoma, Wash.	318	1.6087	1.6683	0.9643	0.80426	1.0927	1.5478	1.5100	131, 400
Fresno, Calif.	333	1.6845	1.6567	1.0168	0.84805	1.1364	1.8874	1.9149	166, 635
Orlando, Fla.	348	1.7604	1.5597	1.1287	0.94138	1.2298	1.3824	1.5178	132, 079
West Palm Beach, Fla.	301	1.5227	1.3415	1.1351	0.94672	1.2351	1.1790	1.3001	113, 135
Bakersfield, Calif.	217	1.0977	1.1001	0.9978	0.83221	1.1206	0.9357	0.9361	81, 459
Amarillo, Texas	217	1.0977	1.0706	1.0253	0.85514	1.1435	0.8401	0.8577	74, 637
Wichita Falls, Texas	151	0.7639	0.7926	0.9638	0.80385	1.0922	0.5901	0.5754	50, 071
Colorado Springs, Colo.	208	1.0522	0.7779	1.3526	1.12812	1.4165	0.7113	0.8996	78, 283
Eugene, Ore.	132	0.6677	0.7422	0.8996	0.75030	1.0387	0.8501	0.7883	68, 598
Abilene, Texas	137	0.6930	0.7103	0.9719	0.81060	1.0990	0.7944	0.7794	67, 823
Odessa, Texas	125	0.6323	0.6537	0.9673	0.80677	1.0952	0.5631	0.5506	47, 913
Santa Barbara, Calif.	111	0.5615	0.5644	0.9949	0.82979	1.1182	0.4475	0.4468	38, 881
Midland, Texas	94	0.4755	0.4906	0.9692	0.80835	1.0968	0.3243	0.3176	27, 638
Lawton, Okla.	126	0.6374	0.4806	1.3262	1.10610	1.3945	0.3537	0.4403	38, 315
Billings, Mont.	98	0.4958	0.4712	1.0522	0.87758	1.1660	0.4361	0.4540	39, 507
San Angelo, Texas	69	0.3490	0.4565	0.7645	0.63762	0.9260	0.3407	0.2817	24, 514
Great Falls, Mont.	90	0.4553	0.4472	1.0181	0.84914	1.1375	0.3905	0.3966	34, 512

[a]Forecast by U.S. Bureau of Public Roads, Office of Planning, unpublished.
[b]Regression coefficient of 1960 to 1950 ratio of the percent share of total population related to 1960 to 1950 ratio of the percent share of automobiles available.
[c]Column 5 plus the constant in the forecast equation, 0.28840.
[d]Column 7 times column 6. Results adjusted to add to 100 percent.
[e]Independently forecast total of 8,702,000 distributed on forecast 1975 percent shares in column 8.

Source: Adapted from data of U.S. Bureau of the Census; stepwise multiple regression and total forecast estimates from Bureau of Public Roads, Office of Research and Development.

and James McCarthy of the Bureau of Public Roads Office of Planning. The percentage distribution of the population was calculated for 1975 and 1960. The 1975 to 1960 ratios of percent shares were then derived, and these ratios were then multiplied by the regression coefficient. The results for each area were added to the constant in the forecast equation to get an estimate of the ratio of change from 1960 to 1975 in each urbanized area's share of automobiles available. The estimated ratios of change are then applied to the 1960 percent distribution of automobiles available to get a percent distribution for 1975. The new percent shares for 1975 are then applied to an independently forecast total of automobiles available in all Type A areas in 1975 (last column). The forecast of this control total is based on state-by-state forecasts of automobile registrations prepared by state highway agencies. The same procedure was followed in developing 1990 forecasts (Table 4).

Usefulness of Forecasts

The projected numbers of automobiles available in 1975 and 1990 can be used as indicative of the total number of automobiles that would be available in an urbanized area in 1975 and 1990, should the 1950 to 1960 relationship between growth in population and automobiles available be maintained.

Recent trends in highway construction, particularly of urban freeways, indicate that this relationship is likely to be maintained. These trends in Type A areas have generally

TABLE 4

PREDICTED AUTOMOBILES AVAILABLE IN TYPE A AREAS FOR 1990

Urbanized Area	Population					Automobiles Available			
	1990		Percent of Total, 1960	Ratio of Percent Shares, 1990-1960	Column 4 Times 0.83404[b]	Ratio of Percent Shares, 1990-1960[c]	Percent of Total		Forecast for 1990[e]
	Number[a] (thousands)	Percent of Total					1960	1990[d]	
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
Los Angeles-Long Beach, Calif.	12, 950	43.9803	50.3742	0.8731	0.72820	1.0166	56.9830	52.0886	6, 547, 536
San Diego, Calif.	2, 800	9.5093	6.4910	1.4650	1.22187	1.5103	5.4048	7.3399	922, 625
San Jose, Calif.	1, 280	4.3471	4.6798	0.9289	0.77474	1.0631	5.9324	5.6708	712, 820
Phoenix, Ariz.	1, 580	5.3659	4.2854	1.2521	1.04430	1.3327	3.7263	4.4653	561, 288
Sacramento, Calif.	1, 220	4.1433	3.5083	1.1810	0.98500	1.2734	3.3444	3.8294	481, 356
San Bernardino-Riverside, Calif.	770	2.6150	2.9307	0.8923	0.74421	1.0326	2.4786	2.3014	289, 286
St. Petersburg, Fla.	905	3.0735	4.8638	0.6319	0.52703	0.8154	2.0917	1.5336	192, 774
Fort Lauderdale-Hollywood, Fla.	1, 100	3.7358	2.4835	1.5042	1.25456	1.5430	2.2323	3.0971	389, 305
Albuquerque, N.M.	770	2.6150	1.8725	1.3965	1.16474	1.4531	1.0952	1.4310	179, 877
Tucson, Ariz.	1, 020	3.4641	1.7654	1.9622	1.63655	1.9250	1.5758	2.7276	342, 859
Spokane, Wash.	450	1.5283	1.7615	0.8676	0.72361	1.0120	1.5615	1.4209	178, 607
Tacoma, Wash.	453	1.5385	1.6683	0.9222	0.7692	1.0576	1.5478	1.4720	185, 030
Fresno, Calif.	470	1.5962	1.6567	0.9635	0.8036	1.0920	1.8874	1.8532	232, 947
Orlando, Fla.	530	1.8000	1.5597	1.1541	0.9626	1.2510	1.3824	1.5550	195, 464
West Palm Beach, Fla.	460	1.5622	1.3415	1.1645	0.9712	1.2596	1.1790	1.3354	167, 860
Bakersfield, Calif.	300	1.0188	1.1001	0.9261	0.7724	1.0608	0.9357	0.8925	112, 187
Amarillo, Texas	326	1.1071	1.0706	1.0341	0.8625	1.1509	0.8401	0.8694	109, 284
Wichita Falls, Texas	215	0.7302	0.7926	0.9213	0.7684	1.0568	0.5901	0.5607	70, 480
Colorado Springs, Colo.	384	1.3041	0.7779	1.6764	1.3982	1.6866	0.7113	1.0787	135, 593
Eugene, Ore.	192	0.6521	0.7422	0.8786	0.7328	1.0212	0.8501	0.7806	98, 121
Abilene, Texas	195	0.6623	0.7103	0.9324	0.7777	1.0661	0.7944	0.7615	95, 721
Odessa, Texas	179	0.6079	0.6537	0.9299	0.7756	1.0640	0.5631	0.5387	67, 715
Santa Barbara, Calif.	150	0.5094	0.5644	0.9026	0.7528	1.0412	0.4475	0.4189	52, 656
Midland, Texas	135	0.4585	0.4906	0.9346	0.7795	1.0679	0.3243	0.3114	39, 143
Lawton, Okla.	238	0.8083	0.4806	1.6818	1.4027	1.6911	0.3537	0.5378	67, 601
Billings, Mont.	157	0.5332	0.4712	1.1316	0.9438	1.2322	0.4361	0.4832	60, 738
San Angelo, Texas	76	0.2581	0.4565	0.5654	0.4716	0.7600	0.3407	0.2328	29, 263
Great Falls, Mont.	140	0.4755	0.4472	1.0633	0.8868	1.1752	0.3905	0.4126	51, 864

[a]Forecast by U.S. Bureau of Public Roads, Office of Planning, unpublished.
[b]Regression coefficient of 1960 to 1950 ratio of the percent share of total population related to 1960 to 1950 ratio of the percent share of automobiles available.
[c]Column 5 plus the constant in the forecast equation, 0.28840.
[d]Column 7 times column 6. Results adjusted to add to 100 percent.
[e]Independently forecast total of 12,570,000 distributed on forecast 1990 percent shares in column 8.

Source: Adapted from data of U.S. Bureau of the Census; stepwise multiple regression and total forecast estimates from Bureau of Public Roads, Office of Research and Development.

encouraged urbanization to continue in the traditional low-density land-use patterns that are conducive to automobile travel. If change should occur in this type of urban development, it would likely be at a very gradual rate since these communities are heavily committed, in terms of investment, to highway transportation and the type of urban development that accompanies this form of transportation. Considering the acceptability of the automobile to the public in Type A areas and the life of a highway, it does not seem politically feasible, under the local democratic process, to radically alter the course of urban development and/or the accumulation of automobiles.

The usefulness of the projected number of automobiles available for any single urbanized area depends on several considerations on the part of the user:

1. What is the purpose for which the forecast is needed and the degree of reliability in the forecast figure that the purpose requires?

2. Do the measures of reliability of the forecasting equation satisfy the first consideration?

3. Is the population forecast, which determines the automobile forecast, acceptable in view of the first-hand knowledge of local growth prospects?

4. Can the forecast totals of automobiles available in 1975 and 1990 be reasonably attained in view of major geographic, social, economic, or other constraints?

SUMMARY

This paper has described a method of projecting the number of automobiles available by urbanized area. The method involved the use of the following: urbanized area classifications; data on 1950 to 1960 shifts in shares (among the areas in each type) of the factors associated with increases in automobile availability; multiple-regression analyses of these shifts; development of estimating equations; and the use of independent forecasts at the national and state levels for deriving totals for each class using a stepdown technique.

The classification of urbanized areas into transportation types and regions proved to be useful analytical bases. Differences in the construction of the estimating equations show that factors associated with growth in automobile availability differ from one area type to another, and between regional locations. It was the classification, along with the shift-share approach, that overcame to a large extent the influence of such widely diverse elements as area size, density, and age, and permitted the influence of more relevant factors to come to light.

Type A Areas

In the case of the areas classified as Type A, change in total population (X_2) was the only independent variable found significantly related to growth in automobile availability (Table 1). These are the automobile-oriented areas of the Far West, Southwest, and Florida in which there is little or no alternative mode of transport from which to choose. Typically, these areas are spread out at low density and with considerable distances between residence and work and other locations. An automobile is, therefore, a necessity that a worker is likely to acquire at his earliest opportunity. Forecasts for these areas to 1975 and 1990 presume the continued expansion of these areas at the low, multinucleated densities that are conducive to automobile travel.

Type E Areas

At the other extreme, for areas classified as Type E, the one independent variable significantly related to increased automobile availability is the increase in high-income families (X_6). In these areas, which are not entirely committed to automobile travel, there is often the choice of an alternate mode such as bus, commuter train, or rail mass transit. These areas, typically, are heavily oriented toward a high-density central core that was established before the automobile era and are, therefore, not conducive to heavy automobile traffic. With the high cost of owning, insuring, operating, maintaining, and parking a car in these areas, it is not surprising that an increase in automobile availability should be a function of high-income families.

Other Types

Change in central city population (X_3) emerged from the analysis as one of two variables with positive relationship to change in automobile availability in area Types B, C, and D (Table 1). This result was due mainly to the fact that, for many small areas in each type, the central city comprises most, or almost all, of the entire urbanized area. The urban fringe population is often a small proportion of the area total. Shifts in shares of automobiles available between the areas in each of these types were, therefore, associated with shifts in the more heavily weighted central city population. In other words, there is a predominance of urbanized areas, with 70 or 80 percent or more of their populations in small- and medium-size central cities, in which automobile travel is not so constrained.

Another reason for the central city being an important factor in these analyses is the dominance of the central city in some of the large urbanized areas that have high levels of automobile availability. These central cities cover large land areas at low densities. Included are such areas as Houston, Dallas, and Oklahoma City.

REFERENCES

1. Bottiny, Walter H., and Goley, Beatrice T. A Classification of Urbanized Areas for Transportation Analysis. Highway Research Record 194, p. 32-61, 1967.
2. Woodbury, Coleman. A Framework for Urban Studies. HRB Spec. Rept. 52, 1959, 29 pp.
3. Wynn, F. Houston. Intracity Traffic Movements. HRB Bull. 119, p. 53-68, 1956.