DEMAND FOR BUS TRANSIT IN U.S. URBANIZED AREAS

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Introduction

The recent energy crisis has forced all levels of government to become more responsive to the pressures of public transit interest groups promoting the revitalization of public transit systems in urban areas across the United States. Intra-city bus systems are important components of the entire United States passenger system. Compared with subways and rail passenger systems, bus systems offer greater access to more residents living near urban routes connecting shopping and workplaces.

However, because of declining patronage, local bus transit systems typically operate with huge deficits, and bus transit is increasingly being looked upon as a public good to be provided by society in a fashion similar to police and fire protection. Federal and local funding to maintain and operate these systems are becoming unavoidable. The federal Mass Transportation Assistance Act of 1974 provided $11.8 billion to be spent on urban transit systems over a six year period. One third of this amount was to be spent for local operating assistance and for upgrading existing service. As governments at all levels want and try to reduce the level of subsidies to these financially plagued systems, they need more reliable information on factors determining transit ridership. Moreover, a comprehensive analysis of the factors affecting demand for bus service across urbanized areas is important for public policy not only for transportation investment planning at the federal and local levels, but also for formulating national energy policies.

The purpose of this paper is to provide empirical estimates of the factors affecting the demand for bus service in large, medium, and small urbanized areas across the United States. The study uses data compiled in the *1974 National Transportation Report* for bus transit systems in urbanized areas throughout the United States.

Past research on demand for bus service can be classified into three main groups. The first group used city-specific data to estimate demand. The second group tried to explain variations in the proportion of users of public transit between zonal pairs within urban areas or between zones across urban areas. The third group attempted to explain variations in the use of public transit on individual transit routes. In addition, other studies attempt to explain decisions regarding choice of travel mode at the household or individual level between zone pairs within an urban area or for a specific city. (Quarmby [16], Lave [12], Warner [25], and McFadden [13]).

Most previous studies, such as Kain [10] and Beesley and Kain [1], were undertaken in the late 1960s and used data reflecting conditions at least two decades in the past (e.g., Kain uses 1953 data). Past conditions may not accurately represent current relationships. Furthermore, the bulk of the existing empirical evidence is city-specific in that the estimates of the regression

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coefficients for independent variables explaining transit use are for *individual* cities. Consequently, the results cannot be used to infer the nature of the relationships for urban areas which have not been studied. In this study, we specify a demand function for bus service (using 1972 transportation data) for all urbanized areas across the United States as well as demand functions for bus transit for urban areas classified by population sizes. In what follows, the responsiveness of demand to transportation system characteristics and urban structure and socioeconomic variables are analyzed in a manner that was not previously possible because of data limitation.

The second section outlines the basic model of urban demand for bus travel and discusses the variables in the model. The third section presents ordinary least squares estimates of the model parameters and compares them with results reported in other studies. Also, comparisons are made among regression results for urbanized areas that are broadly classified by population size. The last section summarizes our findings and their policy implications.

Model Of Urban Demand For Bus Service

The model of bus transit demand used in this study is:

$$B = B(Y, H, C, A, D, N, M) \tag{1}$$

$$\text{where} \quad \partial B/\partial C,\ \partial B/\partial D,\ \partial B/\partial N > 0$$
$$\text{and} \quad \partial B/\partial H,\ \partial B/\partial A,\ \partial B/\partial M < 0$$

Table 1 shows the symbols and definitions of the variables in the model. This section discusses the variable and partial derivative sign specification of the model.

The demand for bus service has generally been specified to be related to a price measure, income, time cost of travel by competing modes (bus and automobile), and a variety of urban structure and socioeconomic variables (for example, population, congestion, topography of the urban area, etc.). The transportation system data used in this study is obtained from the *1974 National Transportation Report.* The socioeconomic data for the entire cross-section of U.S. urbanized areas is obtained from the *City and County Data Book.* The dependent variable in the demand function is the proportion of workers in a given urbanized area who use the bus for the journey to work. This measure is consistent with the practice in the earlier work in the literature (Kain [10], Dajani and Sullivan [3], Sammons and Hall [17] are examples), where demand was estimated using the percentage of travelers either at the zone level or city level.

Most modeling efforts for bus transit demand (see Wabe and Cole [24], Boyd and Nelson [2], Fairhurst and Morris [5], and Nelson [15] for a discussion) have argued that demand for bus service is closely related to the money cost (C) of travel. Various measures of this variable were tested in this group of studies, including bus fares measured in real terms, nominal fares, and fares per passenger mile. However, it has been argued in the modal choice literature (Quarmby [16], Lave [12], McFadden [13], McGillivray [14], Warner [25], and Williams and Smith [26]) that travelers tend to choose the cheaper mode available to them for travel activities. In these studies, the monetary variables were expressed in terms of ratios or differences in the money cost of competing modes. Quarmby [16] tested both the ratio and the difference forms of this variable and found that the difference form explained the preferred choice better. (See also McFadden [13], Lave [12], and Williams and Smith [26] for additional empirical evidence on the difference specification form.) In this study, the money cost of travel variable is expressed as the cost of making a trip by automobile minus bus fares. We hypothesize that the coefficient for the money cost of travel variable in equation (1) is positive, since workers can be expected to use the cheaper mode (i.e., $\partial B/\partial C > 0$).

Time costs of travel by bus also should affect the use of bus transportation (Gaudry [8] and Garbode and Soss [7]).[1] Travel time components usually are used to measure the quality of service provided. One such component is the frequency of bus service, here measured in terms of average peak hour headway time (H), the time interval in minutes between bus arrivals on a given route. Besides in-vehicle trip time, travelers can be expected to consider the frequency of service because providing more buses per hour on a given route reduces waiting time and makes trips by bus more convenient and less time consuming. Consequently, increases in the average headway of buses can be expected to be accompanied by decreases in the proporation of users of the bus service (i.e., $\partial B/\partial H < 0$).[2]

The concentration of population (D) will affect the use of bus transit. Population density provides a proxy measure of the general traffic and the physical conditions, such as congestion, under which bus service is provided within an urbanized area. The more congested the traffic, the greater the inconvenience of bus travel and the longer the average bus trip. Congested travel conditions should discourage users of both automobiles and buses. However, high density areas typically have better structured transportation systems that are capable of providing adequate service to its users. This fact coupled with other economic restraints, such as high parking charges, would mitigate against the use of automobiles and can be expected to encourage greater use of public transportation. Thus, population density and bus transportation use are expected to be directly related (i.e., $\partial B/\partial D > 0$).

Other studies of urban travel suggest that income is an important variable because, *ceteris paribus,* higher income travelers are more likely to use the automobile rather than public transit, even though it is the more expensive mode, because they place a higher value on their travel time savings and because of amenities of the automobile, such as greater convenience and comfort. However, in the literature there is no general agreement on the statistical significance of income on demand for bus service. The variations in the significance of the income variable for previous studies may depend on the different measures of income used in the respective studies. A variety of measures such as the income of the employed worker, real income, the percentage of the population with annual incomes under \$3,000 and the percentage of the population with annual incomes over \$10,000 are some of the income measures used in the different studies. As Nelson [15] suggests, one would expect income changes to affect demand for bus service for different income classes in different directions. Accordingly, we attempt to isolate the

[1]In earlier stages of this study, in-vehicle time measured by average passenger trip time was included in the specification of the basic regression model but was deleted when it was found that in-vehicle time was not significant in any of the preliminary runs and its deletion did not significantly affect the values of the coefficients of other variables, their levels of significance, nor the R^2 values.

[2]Domencich and Kraft [4] provide ample evidence that service quality is an important factor for potential bus users.

effect of an income distribution variable (Y) on demand for bus service. Our income distribution variable is the proportion of households with incomes in the lower middle to middle income ranges of $5,000 to $8,000 in 1970. It is often suggested that central cities have lost high income residents to the suburbs. But the empirical findings of a recent study by Kern [11] on this phenomenon indicate a sharply contrasting pattern to this perceived popular view: large numbers of lower middle and middle income families who are moving from the central city to the suburbs, and increases in the number of high income families living in the central city. The strong evidence of growth of lower middle and middle income families in the suburban areas provides an opportunity for us to examine the effect of this pattern of residential choice on demand for bus service. That is, if a large proportion of households in this income range are likely to be scattered in the suburban communities where bus transportation service is usually inadequate for their needs, then we can expect the income distribution variable (Y) to be inversely related to bus usage (i.e., $\partial B/\partial Y < 0$).

In practice, the degree of automobile ownership (A) is used as a measure of the availability of alternative transportation services having greater comfort and convenience than bus transportation, and hence, it is expected to vary inversely with the demand for bus transportation (Wabe and Cole [24] and Nelson [15]) (i.e., $\partial B/\partial A < 0$).

The industrial structure of employment of an urbanized area is believed to affect the demand for bus transportation for travel from and to peripheral suburban communities. Urbanized areas with high central concentrations of manufacturing employment (M) can be expected to attract workers who live in these suburban communities. Because suburban communities typically are not well served by bus transportation, commuters tend to rely upon automobiles for the journey to work. This line of reasoning leads to positing an inverse relationship between the percentage of the labor force employed in manufacturing and bus transportation use. Because of the rapid suburbanization of central city residents during the 1960s and 1970s, we would expect the percentage of the labor force employed in manufacturing to vary inversely with the proportion of workers who use bus transportation for the journey to work (i.e., $\partial B/\partial M < 0$).

Other demographic characteristics of the population are expected to influence the demand for bus transportation. We include the percentage of the population that is nonwhite (N). Black workers are more concentrated in lower paying, lower status job categories. Income and racial discrimination in the market for housing forces them to choose inadequate housing in the core areas of the older large cities.[3] In many of these cities a large proportion of blacks both live and work in the central city. Accordingly, residential segregation and economic discrimination are two important factors affecting ghetto residents' transportation accessibility and their demand for bus transportation. One expects that members of this group will take more trips by bus since it is relatively more accessible. Thus, the percentage of nonwhite population is expected to have a positive effect on use of bus service (i.e., $\partial B/\partial N > 0$).

Before proceeding to the model specification and results, it is necessary to

[3]Other factors may also explain this pattern of concentration, such as a greater supply of low priced housing, better transportation facilities linking residence to workplace, and the greater supply of low skilled jobs.

discuss several special problems associated with the use of population as an independent variable in bus demand studies (Wabe and Cole [24] and Frankena [6]). It has been suggested that the population of the area can be used as a proxy for a number of factors explaining the demand for bus service. Wabe and Cole [24] use the population variable to measure the effect of the size of the area served. In other words, population is used as a proxy for the distance of the trip. The authors argue that the larger the urban area, the longer the average bus journey and the more expensive the trip in terms of time and money costs. However, this effect may be reflected in the money cost variable in the model. Others, for example Frankena [6], include the population variable in the model as a proxy for speed (this effect is more adequately measured by a residential density variable) but Frankena questions its use as a proxy for the size of area served, and he argues that use of the population variable introduces both observation and specification error.[4] As noted previously, population can be considered to represent any number of factors explaining bus usage. Therefore, no straightforward explanations can be offered on its coefficient as tests of specific hypotheses. To overcome these problems associated with the population variable, we stratify our sample by size of urban area measured by population and analyze the results between size groupings.

Empirical Results

In order to estimate the partial derivatives in the model of the demand for bus transportation, equation (1), the statistical model was specified as being the following linear regression model:

$$\text{(2)} \quad B_j = a_o + a_1Y_j + a_2H_j + a_3C_j + a_4A_j + a_5D_j + a_6N_j + a_7M_j \qquad j = 1, \ldots, n$$

$$\text{where } a_3, a_5, a_6 > 0 \text{ and } a_1, a_2, a_4, a_7 < 0$$

In addition to showing the symbols and definitions of the variables used in the regression model, Table 1 also shows the sources of data for each variable.[5]

The ordinary least squares estimates of the demand equations for a cross-section of urbanized areas stratified by four population classes are presented in Table 2.[6] The numbers in the parentheses below the estimated coefficients are t-statistics for the null hypothesis of no association.

When urbanized areas of all sizes are considered, equation (1) in Table 2 shows that all the estimated coefficients have the expected signs and, except the nonwhite variable, are all significant determinants of the demand for bus transportation.[7] These variables explain about 61 percent of the variation in the

[4]Frankena [6] notes that one must first consider whether population is proportional to area or to a power of area. If $P = \alpha\pi^{C/r}$ where $r \neq 1$ and π is area served, then if P is used rather than P^r as a measure of area served, there will be a specification error. If, however, the relationship between P and π is stochastic, then using either P or a power of P as a proxy for π will result in an observation error.

[5]The cost of operating an automobile was assumed to be $0.11 per mile, a figure which is based on data from the U.S. Department of Transportation, Federal Highway Administration, Office of Highway Planning, 1972.

[6]Cross-sectional samples have the potential for heteroscedastic errors. We tested for heteroscedasticity by examining the residuals from all the equations in Table 2, using the Glejser [9] test. We regressed the absolute values of the residuals on each explanatory variable. Using the standard test of significance of these coefficients, we found that we cannot reject the hypothesis of homoscedasticity in any equation.

[7]Multicollinearity between independent variables does not seem to be a serious problem. The correlation between any pair of independent variables for each estimated equation by population class (e.g., combined, large, medium and small) is less than .50 in absolute value.

TABLE 1. VARIABLES AND DATA SOURCES

Symbol	Variables	Data Source
Dependent Variable:		
B	Percentage of workers in an urbanized area using bus transportation for the journey-to-work	a
Independent Variables:		
Y	Percentage of households in an urbanized area with incomes between $5,000 and $8,000	a
H	Average peak hour headway in an urbanized area (minutes)	b
C	Average cost of trip by automobile minus the average bus fare (cents)	b, d
A	Percentage of households in an urbanized area with one or more automobiles	a
D	Population per square mile of land in an urbanized area	d
N	Percentage of the population of an urbanized area that is nonwhite	d
M	Percentage of the employed labor force in manufacturing in an urbanized area	d
u	Disturbance term	

Data Sources:

a	U.S. Department of Transportation [22].
b	U.S. Department of Transportation [20].
c	U.S. Department of Transportation [21].
d	U.S. Department of Commerce, Bureau of the Census [18].

TABLE 2. REGRESSION ESTIMATES OF DEMAND FOR BUS TRANSPORTATION BY U.S. URBANIZED AREAS

	Equation	Intercept	Y	H	C	A	D	N	M	n	F	R^2
Urbanized Areas	(1)	43.8820	- .1559** (-2.80)	- .0524*** (-3.50)	.0300*** (3.41)	- .4409*** (- 9.81)	.0008*** (3.95)	.0189 (0.97)	- .0312* (-1.71)	198	43.22	.614
	(2)	43.1039	- .1355* (-2.54)	- .0539*** (-3.88)	.0351*** (4.32)	- .4348*** (-10.81)	.0008*** (4.04)		- .0314* (-1.87)	214	54.02	.610
Urbanized Areas: 500,000 or More Persons	(3)	50.3168	- .2390* (-1.95)	- .0788 (-1.52)	.0022 (0.10)	- .4694*** (- 3.89)	.0002 (0.34)	.1437* (2.34)	.0030 (0.05)	44	11.40	.689
	(4)	53.6489	- .2498* (-2.26)	- .0801* (-1.65)		- .4978*** (- 5.86)		.1442* (2.47)		44	21.50	.688
Urbanized Areas: 100,000 to 500,000 Persons	(5)	46.9791	- .2009** (-2.98)	.0025 (0.15)	.0281** (2.74)	- .4558*** (- 9.72)	.0001 (0.41)	.0156 (0.80)	- .0700*** (-3.55)	107	19.82	.584
	(6)	48.8049	- .2045*** (-3.37)		.0279** (2.97)	- .4692*** (-11.34)			- .0712*** (-3.88)	111	38.45	.592
Urbanized Areas: Less Than 100,000 Persons	(7)	44.9744	.1134 (1.33)	- .0013 (-0.06)	.0153 (1.08)	- .5226*** (- 6.75)	.0004 (1.46)	- .0853** (-2.86)	- .0162 (-0.64)	47	10.80	.660
	(8)	42.0808				- .4580*** (- 8.51)		- .0423* (-1.65)		61	37.31	.563

* denotes that the coefficient is significant at the 0.1 level or better
** denotes that the coefficient is significant at the 0.01 level or better
*** denotes that the coefficient is significant at the 0.001 level or better

demand for bus transportation among urbanized areas. Equation (2) shows that when percentage nonwhite population is deleted, the coefficients of the remaining variables remain essentially unchanged and are significant. Thus, among urbanized areas of all sizes, the demand for bus transportation varies directly with population density and comparative trip cost and varies inversely with the degree of automobile ownership, headway time, income distribution, and the extent of manufacturing employment.

For large urbanized areas, with populations of 500,000 or more persons, equation (3) shows that the significant variables are income distribution, automobile ownership, and percentage nonwhite population, each of which has the expected signs. Because the coefficient of headway time in equation (3) was close to being significant at the 0.1 level or better, it was included in the specification of equation (4) with the significant variables from equation (3). There is no substantial difference between the coefficient estimates of the common variables in equations (3) and (4), and both equations explain 69 percent of the variation in the demand for bus transportation among the large urbanized areas.

For medium-sized urbanized areas, with 100,000 to 500,000 persons, equation (5) shows that the significant independent variables are income distribution, comparative trip cost, automobile ownership, and percentage manufacturing employment; all of these variables have the expected signs.Equation (6) indicates once again that when the insignificant variables — headway time, population density, and percentage nonwhite population — are deleted, the coefficients of the remaining variables remain essentially unchanged and significant. These variables explain about 59 percent of the variation in the demand for bus transportation among the medium-sized urbanized areas.

Equation (7) shows that, for small urbanized areas with populations of less than 100,000 persons, the only significant independent variables are automobile ownership and percentage nonwhite population; however, the coefficient for percentage nonwhite population is negative. Equation (8) reveals that when the insignificant variables in equation (7) are deleted, there is some change in the magnitudes of the coefficients of the automobile ownership and percentage nonwhite population variables; furthermore, the R^2 value dropped from 0.660 to 0.563.

Further insight can be gained by comparing these results in terms of the significance of the variables for different classes of urbanized areas. Income distribution was a significant determinant of the demand for bus transportation for the combined, large, and medium urbanized areas, but not for small urbanized areas. In small urbanized areas, it is relatively easier to service outlying residential areas where lower middle to middle income workers reside so that it is understandable that the systematic inverse relationship between B and Y that appears in the regression analyses for the other classes does not appear for the small urbanized areas.

Headway time is highly significant for the combined urbanized areas, but, except for equation (4), is not significant in any of the regressions for any of the other classes of urbanized areas. This suggests that, although there are insignificant effects of headway time upon demand for bus transportation within classes of urbanized areas, there are significant differences between the urbanized areas.

Comparative trip cost is significant for the combined and medium urbanized areas, but not for the large and small urbanized areas. To gain a possible understanding of these relationships, consider the reasonable assumption that geographic area increases with increasing classes of urbanized area (defined with respect to population). In small urbanized areas, workplaces can be expected to be relatively concentrated near the central cores of the urbanized areas. In medium areas, workplaces can be expected to be located in more disperse patterns with many, especially older, workplaces being located in the central cores of urbanized areas, but with many new industries locating in the more peripheral sections of urbanized areas. In large urbanized areas, there is an even more widespread pattern of workplaces resulting from urban growth processes that involve dispersion of industry and commerce. In the sample, the average percentage of workers using bus transportation for the journey to work increases with increasingly larger classes of urbanized areas, as one would expect with generally increasing average travel distances and higher parking fees in the central core of urbanized areas.[8] But within, say, the class of small urbanized areas, as one goes from a small urbanized area with a small comparative trip cost to one with a relatively larger comparative trip cost, relative costs of using automobiles rather than buses may not be significant enough nor the impact on the budget of workers great enough to induce them to switch transportation modes. As one goes from a medium urbanized area with a small comparative trip cost to one with a relatively large comparative trip cost, one might expect that bus transportation would begin to become more attractive to workers as the opportunity cost of continued use of automobile travel becomes greater; thus, one would expect there to be a greater degree of substitution of bus transportation for automobile travel, where the comparative trip cost becomes large. For large urbanized areas, there may not be appreciable changes of transportation mode in part because many workers in large urbanized areas have better choices of residential locations and thus can find suitable housing relatively near their workplaces, thereby reducing the impact of the cost of journey to work travel on the workers' budgets and therefore, "desensitizing" workers to possibly high comparative trip costs.

The degree of automobile ownership is the only independent variable that is significant for all classes of urbanized areas. It is interesting to note that this variable is the most important and common determinant of public transportation usage in earlier studies.

Population density is significant only for the combined urbanized areas. Like the headway time variable, differences in population density seem to be more important among different classes of urbanized areas than within classes of

[8]The following table shows the average percentage of workers using bus transportation for the journey to work, by class of U.S. urbanized areas.

Classes of Urbanized Areas	Average Percentage of Workers Using Bus Transportation for the Journey-to-Work	Coefficient of Variation	Sample Size
All Areas	4.745	82.822	233
500,000 or more persons	8.825	54.721	44
100,000 to 500,000 persons	4.426	66.607	114
Less than 100,000 persons	2.836	98.784	75

urbanized areas. The significance of population density is consistent with similar findings in Dajani and Sullivan [3], Sammons and Hall [17], and Wabe and Cole [24].

Percentage nonwhite population is a significant determinant of the demand for bus transportation in large and small urbanized areas, but not in medium urbanized areas. Moreover, percentage nonwhite population is inversely related to the demand for bus transportation for small areas. Because of the generally smaller land area of small urbanized areas, the average travel distance to work may be shorter for all workers. Thus, we may expect a greater degree of substitution among transportation modes, especially away from single-rider automobiles and even away from bus transportation and into walking, bicycling, or carpools.

The percentage of the labor force that is in manufacturing is highly significant for medium-sized urbanized areas, but is not significant for large or small urbanized areas.

Summary and Policy Implications

This study analyzes the demand for urban bus transportation using the most up-to-date data available. The results are of independent interest and cannot be compared with previous studies, most of which dealt with specific cities. The model includes transportation-system and socioeconomic explanatory variables such as measures of income distribution, comparative trip cost, automobile ownership, population density, percentage nonwhite population, percentage of the labor force in manufacturing and level of service variables. The income distribution, percentage manufacturing employment, and quality of service measures were not used in any of the previous studies noted. In addition to the regression analysis of the combined urbanized areas, the separate analyses for the classes of large, medium, and small urbanized areas reveal many significant differences in the determinants of the demand for bus transportation in different sized urbanized areas and suggest different bus transportation policies for different classes of urbanized areas.

Some policy implications are clear from the analysis. The significance of headway time in the equations for the combined urbanized areas suggests that differences in quality of service among classes of urbanized areas may be the result of scale factors in transportation technology. The empirical evidence for the large, medium, and small urbanized areas suggests that, in an urbanized area of a given class, improved routing and scheduling that lead to improved bus service would have a significant impact upon the demand for bus transportation in that class.

The findings further indicate that public policies designed to make bus transportation to work cheap relative to the average cost of automobile travel would be effective for medium urbanized areas but not for large or small urbanized areas. Finally, public policies which limit the use of the automobile are most likely to succeed in promoting greater use of bus service for all classes of urbanized areas. However, implementing such policies is likely to be controversial.

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