Abridgment

Demand Analysis of New York Subway System

C.J. KHISTY AND P.J. KAFTANSKI

An econometric analysis of the New York City subway system for the period from 1946 to 1978 is presented in this paper. The purpose of this analysis is to identify those variables that affect mass transit ridership. The multiple regression technique was used. In addition, a stepwise regression was performed to determine which of the independent variables explains the greatest variation in transit ridership. The annual subway ridership is the dependent variable; the independent variables are the transit fare, the level of employment in Manhattan's central business district, the aggregate personal income of New York City's residents, the number of automobile registrations in New York City, and an index of business activity for New York City. Analysis of the results reveals that automobile registrations and central business district employment are the most significant variables that affect subway ridership. The results of this study indicate that capacity restrictions on automobile use, urban development change, and increasing the monetary value of automobile ownership will increase transit ridership.

The purpose of this study is to test the relation between mass transit ridership and the variables that influence ridership in the New York City subway system and then to suggest policy decisions, based on this analysis, to improve transit ridership. This is of utmost importance in terms of federal and state funding of the system, since the New York City Transit Authority forecasts that its operating deficit for this system would approximate $55.3 million in fiscal 1981 and $78.1 million in 1982 (1). The authority believes that these deficits can be made up through additional federal aid and an increase in fare revenue or through expenditure reduction. Alternative solutions are offered based on this study's empirical findings. These solutions center around the concept of increasing mass transit ridership.

PREVIOUS STUDIES

Transit need is a derived demand. In light of this demand, there have been many observations of the significant characteristics that affect mass transit ridership. The First National City Bank (now known as Citibank), in its profile study of New York City, observed that a 50 percent increase in the transit fare in January 1970 resulted in a 5 percent reduction in ridership (2, p. 140). Automobile ownership is also a highly significant factor. For example, the restrictions placed on automobile use during World War II resulted in a decrease in urban automobile travel by approximately 25 percent. One-third of the people who decreased their automobile travel shifted to public transportation (3, p. 6). Pushkarev and Zupan's study indicates that, for trips to the downtown area of New York City, 83.7 percent of zero-car households, 36.7 percent of one-car households, and 15.4 percent of two- or more-car households used mass transit (4, p. 53). Mass transit carries more than 82 percent of all central business district (CBD) workers in New York City. This suggests that capacity restraints significantly influence transit demand. Population density also affects transit use. A higher density encourages public transportation use and discourages automobile use. Transit use is minimal when the density varies between 1 and 7 dwelling units (DUs) per acre, increases sharply when the density is about 7 DUs/acre, and one-half of the trips are made by transit when the density is greater than 60 DUs/acre (3, p. 6).

Other determinants of transit use could be classified as psychological. These include time, convenience, and comfort (5). Uncertainty of arrival of public transport vehicles and the probability of accidents can also be considered (6, p. 90). These criteria are probably reflected in the public's demand that mass transit facilities and operations provide convenient access to central city locations (e.g., work, school, and shopping). It appears that the main characteristics that influence modal choice are the automobile's ability to provide the traveler with a sense of ownership, free availability, prestige, and comfort (7, p. 22).

The most relevant study (and the one we used as a comparison) is the one conducted by Pushkarev and Zupan for the Regional Plan Association of New York (8). An aggregative time-series analysis (multiple regression) for the years 1947-1975 for the New York City subway system revealed that subway ridership is positively correlated with the level of CBD employment and the level of service (measured in car miles) and is negatively related to automobile registrations and the subway fare (in constant dollars). These variables explain roughly 80 percent of the variation in subway rides.

METHODOLOGY

The analysis covers the years 1946-1978 and considers annual subway ridership as the dependent variable. The independent variables include the transit fare, the level of employment in Manhattan's CBD, aggregate personal income of New York City's residents, the number of automobile registrations in New York City, and an index of business activity for New York City. The business activity index is a measure of the physical output of goods and services in the private sector that consists of (a) factory output; (b) retail activity; (c) wholesale activity; (d) service activity; (e) finance, insurance, and real estate activity; (f) transportation, communication, and public utilities activity; and (g) construction activity.

Statistical Procedure

The method of analysis used in the generalized least-squares procedure is a log-linear or constant elasticity form. The selection of this form is based on the belief that (a) the proposed relationship is linear in nature, (b) the elasticities of transit demand with respect to the independent variables are of great importance in formulating transit policy, and (c) the transformation of the data into a linear function reduces some of the potential problems of a nonlinear function.

This study's form was

$$Y = a + b_1x_1 + b_2x_2 + b_3x_3 + b_4x_4 + b_5x_5$$

where Y is the total number of rides recorded on the subway system of New York City in year t and x_1 through x_5 are the total values of the independent variables recorded in year t - 1. The elasticities with respect to each independent variable are b_1 through b_5 with the constant term a.

In addition to the generalized least-squares procedure, a stepwise regression was performed to determine which of the independent variables explains

Table 1. Multiple regression results.

Equation	Fare: Constant Dollars, X_1	Fare: Current Dollars, X_1	Automobile Registration, X_2	Personal Income: Constant, X_3	Personal Income: Current, X_3	CBD Employment, X_4	Business Index, X_5	R^2	F Value
1a[a]								0.9432	244.75
1b	-0.2035	...	-0.3008	...	...	...	...		
Std. error	0.0273	...	0.0632	...	...	...	...		
F level	55.58	...	22.64	...	...	...	...		
2a[a]								0.9694	475.12
2b	...	-0.2247	-0.2190	...	...	...	...		
Std. error	...	0.0196	0.0486	...	...	...	...		
F level	...	131.49	20.34	...	...	...	...		
3a[b]								0.9480	157.91
3b	...	-0.2743	-0.3548	...	0.0922	...	...		
Std. error	...	0.0443	0.1007	...	0.0669	...	...		
F level	...	38.34	12.42	...	1.90	...	...		
4a[c]								0.9556	123.84
4b	...	-0.1933	-0.3776	...	0.0353	0.5332	...		
Std. error	...	0.0436	0.1737	...	0.0708	0.1781	...		
F level	...	19.62	4.73	...	0.25	8.97	...		
5a[d]								0.9585	64.60
5b	...	-0.1267	-0.2599	...	-0.0492	0.7082	-0.0411		
Std. error	...	0.0697	0.2595	...	0.1331	0.2780	0.2422		
F level	...	3.30	1.00	...	0.14	6.49	0.03		
6a[b]								0.9227	103.44
6b	-0.2081	...	-0.6849	0.2972	...	...	...		
Std. error	0.0268	...	0.1424	0.1196	...	...	...		
F level	60.26	...	23.13	6.18	...	...	...		

[a]Covers 1946-1978. [b]Covers 1949-1978. [c]Covers 1951-1978. [d]Covers 1959-1978.

Table 2. Stepwise regression results.

Independent Variable	Equation	Total R^2
Fare (constant)	1A	0.9143
Fare (constant) and automobile registrations		0.9505
Fare	2A	0.9486
Fare and automobile registrations		0.9694
Fare	3A	0.9188
Fare and automobile registrations		0.9442
Fare, automobile registrations, and personal income		0.9480
Fare	4A	0.9362
Fare and CBD employment		0.9409
Fare, CBD employment, and automobile registrations		0.9551
Fare, CBD employment, automobile registrations, and personal income		0.9556
Fare	5A	0.9155
Fare and CBD employment		0.9406
Fare, CBD employment, and automobile registrations		0.9579
Fare, CBD employment, automobile registrations, and personal income		0.9584
Fare, CBD employment, automobile registrations, personal income, and business index		0.9585
Fare (constant)	6A	0.8353
Fare (constant) and automobile registrations		0.9043
Fare (constant), automobile registrations, and personal income (constant)		0.9227

the greatest variation in transit ridership.

Results

The results of this analysis are summarized in Tables 1-3. All of the equations are significant in explaining transit ridership as measured by each model's F-value at the 99 percent significance level. However, not all of the variables are significant at the 99 percent significance level. Those that are not significant are current personal income in Equation 3, personal income and automobile registrations in Equation 4, and all the variables in Equation 5 (although, at the 0.975 percent level of significance, CBD employment is significant). Autocorrelation is not a problem.

In comparing the elasticity measures of Pushkarev and Zupan's results, some interesting differences appear. Their fare (constant dollar) elasticity measure was -0.12; however, this study reveals that the elasticity with respect to the constant dollar fare is -0.2035 from 1946 to 1978. This implies that subway ridership is more price elastic than previously thought. It is also obvious that the raising or lowering of fares does not contribute to the goals of improving ridership levels and promoting the financial stability of the system.

The elastic measure for automobile registrations differs from Pushkarev and Zupan's study. Their measure is -0.25. This study's measure is -0.219 in Equation 2, -0.3548 in Equation 3, and -0.3776 in Equation 4. As the period of analysis shortens, the elasticity measure becomes less inelastic. This suggests that automobile ownership has a stronger impact on subway ridership than does the fare, especially in the short run. However, part of this trend in elasticity may be due to the increasing level of automobile ownership in New York City. Car ownership increased from approximately 605 000 vehicles in 1945 to 1 500 000 in 1977. As automobile ownership increases, its use as a mode of transportation increases, which makes the trade-off between automobile use and mass transit more significant. Personal income is not a significant variable in determining the overall ridership level.

Pushkarev and Zupan's elasticity measure is 0.7543 for CBD employment. This study's elasticity measures are 0.5332 and 0.7082 in Equations 4 and 5, respectively. This suggests that the level of employment is the most influential variable that affects mass transit ridership in the short run. This would suggest that policies designed to increase employment opportunities in New York City or designed to improve areas that attract people (e.g., parks or cultural areas) would have the effect of increasing mass transit use. But any policy should downplay major improvements in terms of providing

Table 3. Determination of each variable's significance.

Equation	Independent Variable	t-Value	Required t-Value at	t-Statistic	Significant
1	Fare, current dollars	7.46	0.99;30	2.457	Yes
	Automobile registrations	4.76	0.99;30	2.457	Yes
2	Fare, constant dollars	11.47	0.99;30	2.457	Yes
	Automobile registrations	4.51	0.99;30	2.457	Yes
3	Fare, current dollars	6.19	0.99;26	2.479	Yes
	Income, current dollars	1.38	0.99;26	2.479	No
	Automobile registrations	3.52	0.99;26	2.479	Yes
4	Fare, current dollars	4.43	0.99;23	2.50	Yes
	CBD employment	2.99	0.99;23	2.50	Yes
	Income, current dollars	0.50	0.99;23	2.50	No
	Automobile registrations	2.17	0.99;23	2.50	No
5	Fare, current dollars	1.82	0.99;14	2.624	No
	CBD employment	2.55	0.99;14	2.624	No
	Income, current dollars	0.37	0.99;14	2.624	No
	Automobile registrations	1.0	0.99;14	2.624	No
	Business index	0.17	0.99;14	2.624	No
6	Fare, constant dollars	7.76	0.99;30	2.457	Yes
	Income, constant dollars	2.49	0.99;30	2.457	Yes
	Automobile registrations	4.81	0.99;30	2.457	Yes

access to these areas via the automobile. If adequate automobile facilities are part of the policy to improve areas that attract trips, the incentive for using mass transit is diminished.

The last variable in the model is the business activity index. The regression results indicate that this variable is not significant.

Based on the results of this study, policymakers should concentrate on just two variables: CBD employment and automobile registrations.

This analysis is an improvement over the Pushkarev and Zupan model because the equations and the individual elasticity coefficients are more significant, and it accounts for a larger percentage of transit ridership variation with fewer independent variables.

RECOMMENDATIONS AND CONCLUSIONS

The main conclusions of this study are that mass transit ridership is a function of CBD employment and the level of automobile registrations. Therefore, policies implemented to increase mass transit ridership should

1. Create more employment opportunities than currently exist in New York City's CBD and
2. Convince travelers who use the automobile in New York City to switch their modal choice to mass transit.

This can be accomplished through the following means:

1. Implementation of congestion pricing in the CBD,
2. Limitation of the number of parking facilities available in the commercial and retail areas of New York City,
3. Expansion of park-and-ride facilities in the outlying areas of New York City,
4. Improvement of the attraction zones,
5. Imposition of tolls on bridges leading into Manhattan from Queens and Brooklyn, and
6. Informational campaign designed to elicit the public's cooperation in implementing the above strategies.

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