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UNITED STATES OF AMERICA
NUCLEAR REGULATORY COMMISSION

ATOMIC SAFETY AND LICENSING BOARD

Before Administrative Judges:
James P. Gleason, Chairman
Frederick J. Shon
Dr. Oscar H. Paris

In the Matter of	
CONSOLIDATED EDISON COMPANY OF NEW YORK, INC. (Indian Point, Unit No. 2)	Docket Nos. 50-247 SP 50-286 SP
POWER AUTHORITY OF THE STATE OF NEW YORK (Indian Point, Unit No. 3)	April 12, 1983

LICENSEES' TESTIMONY
OF DR. FREDERICK C. DUNBAR ON COMMISSION QUESTION 6

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I. INTRODUCTION AND SUMMARY

My name is Frederick C. Dunbar. I am a Senior Consultant with the firm of National Economic Research Associates, Inc. Both I and the firm specialize in, among other things, the economics of energy and transportation. More particularly, I have studied the economics of urban transportation for the past 12 years and have published extensively on this subject. My qualifications are summarized in Attachment One.

I have been asked by Con Edison and the Power Authority of the State of New York to comment on the transit impacts of an early shutdown of Indian Point. This subject is directly relevant to Commission Question 6 in this proceeding which asks:

> What would be the energy, environmental, economic or other consequences of a shutdown of Indian Point Unit 2 and/or Unit 3?

Con Edison and the Power Authority have argued that closing Indian Point at this time will cause substantially higher electricity costs. These higher costs may be passed on to consumers in the form of higher electricity prices. The Metropolitan Transportation Authority (MTA)--New York City's biggest power consumer--will be particularly hard hit. In response to increased power costs, the MTA will have to increase fares and/or reduce service. This, in turn, will have adverse consequences on employment and economic activity in New York City.

I have quantified these impacts assuming that the MTA's power costs would increase 29.5 percent annually through 1986 (which is about $43.8 million more than the MTA budgeted for power last year). My results, which like all estimates of this sort are subject to some uncertainty, are as follows:

1. Total transit operating costs would increase 2.2 percent. To recover these increased expenses, the MTA would be forced either to increase fares or to reduce service (to save costs). In all likelihood, a fare increase would be used.
2. The amount of the fare increase needed to make up the deficit (after accounting for the effects of lost ridership) would be 6 cents (or 8 percent above current fares). This would cause nearly 3 percent less ridership.
3. This, in turn, would mean a loss of nearly 11.4 thousand jobs and $323 million in annual income for New York City. It would also mean $34 million less in annual city tax revenues.
4. If, alternatively, transit service were reduced to free up funds for increased power costs, then the impacts would be even more severe. This would cause a 4 percent decline in ridership which would mean a loss of almost 15.3 thousand jobs, $434 million in annual income, and $46 million in annual tax revenues all for New York City.

The remainder of my testimony describes how I arrived at these conclusions.

II. BACKGROUND

Public transit has long been an integral part of life and commerce in New York City. The system includes large bus, subway and commuter rail networks which carry over 7 million passenger trips per day throughout the tri-state region.[1] Over half of these trips are to the Manhattan Central Business District (the CBD)--that part which is below 60th Street. Responsibility for the system is shared among 138 public and private operators, although 80 percent of ridership is on operations which make up the MTA.

There are dozens of statistics which show the magnitude and importance of the MTA on New York City's and the region's economy. A few salient facts are presented below:

1. Proportionately, more people use transit here than anywhere else in the country. The metropolitan region has less than 8 percent of the national population yet it has 40 percent of the nation's passenger miles on public transportation.[2] Better than two-fifths of all workers in the City and its suburbs use public transportation to get to work.[3] Other cities aren't even close: the rail rapid transit cities of Chicago, Boston, San Francisco, Philadelphia and Washington all lie between 14 and 18 percent;

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1 Tri-State Regional Planning Commission, "Annual Transportation Report," June 1982, p. vi ("Annual Report").

2 Tri-State Regional Planning Commission, "Regional Public Transportation at a Glance: 1979" (New York, NY), ("Glance").

3 U.S. Department of Labor, "New York City Job Recovery Mostly Limited to Manhattan, With Three-year Gain of 110,000 Private Sector Jobs," Bureau of Labor Statistics, Middle Atlantic Region (New York: March 27, 1981), pp. 3, 4.

for most major urban areas the proportion is less than 10 percent.[4]

2. Looking only at travel to and from the Manhattan CBD, over two-thirds of all trips, and over three-fourths of all work trips, are made by transit.[5]

New York City's subways are a vital link in the network. Almost half of the tri-state region's travel by public transportation is made on the subway.[6] The Manhattan CBD is critically dependent on subways: an astonishing 94 percent of peak-hour public transportation travel from the four subway boroughs (North Manhattan, Brooklyn, the Bronx and Queens) to the CBD is made by subway.[7]

The subway system is, of course, powered by electricity. Consequently, the cost of power is a substantial item in the MTA's budget. As shown in Table 1, electricity was expected to cost $149 million in this past fiscal year--this is about 7 percent of the total operating cost.

What would happen if the cost of power were to increase? To answer this question, it is necessary to describe the current plight of the MTA.

Though a vast number of people prefer the mass transit system to other modes of travel, it is currently an object of some abuse to its ridership. The main reason for this is that service has deteriorated persistently and substantially over the past decade. The decline in service has not been matched by decreasing fares.

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4 Id.

5 Tri-State Regional Planning Commission, "The Effects of Fare Changes on Public Transportation Ridership and Revenues," (New York: March 1980), pp. 9, 21, B-1.

6 Glance.

7 Tri-Sate Regional Planning Commission, "Interim Technical Report 2121: The B-5 Strategy," (New York: July 1977), p. 3 ("ITR 2121").

The reason for the service decline is that in the face of rising costs and declining ridership, the MTA has consistently fought to keep fares and subsidies low with the consequence that plant and vehicles have not been well maintained. There is nothing new in this approach to managing mass transit: the New York subway has been in various states of crisis since the 1920's.[8] Except for a brief period twenty years ago, there has been progressive decay of plant and equipment over this entire time.

Looking at the time from 1968, when the MTA was formed to solve this problem, the figures on ridership, revenues and costs tell the story. As shown in Table 2, costs have increased much faster than revenues. As a result, the MTA's operating deficit grew from $97 million in 1968 to $1,822 million in 1981. Though ridership declined somewhat (by 25 percent) over this period, the major culprit was cost per trip. While fares increased at about the rate of inflation, the cost per trip increased by nearly three times the inflation rate.

MTA management faces a serious dilemma when costs go up. There are basically only four strategies that can be considered: service cutbacks and deferred maintenance, productivity increases, fare increases, and higher deficits and subsidies. At various times, some of these strategies are infeasible.

Productivity increases, for example, seem to be highly remote. As a practical matter, there are only two sources for increased productivity: labor practice changes and new technology. Labor productivity increases are unlikely. The much heralded productivity savings from the 1980 labor contract (then estimated to be $30 million) never materialized. Moreover, recent research shows that potential labor savings in transit are much less than had been commonly

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8 See Peter Derrick, "The N.Y.C. Mess: Legacy of the 5¢ Fare," Mass Transit, July 1981, pp. 12, 13, 26, ("Derrick").

believed.[9] Similarly, new technology has not been as productive as the old. Most people are now familiar with the problems of the new Grumman and GM buses. In addition, new rail systems in Washington and San Francisco required a long shakedown period--as will the new light rail vehicles in Boston.

This means that if service and plant is to be maintained, the MTA either will have to raise fares or seek outside funding. Both options are politically unpopular. It is a fact of life that neither public officials nor the media will advocate fare hikes, and they will often decry them when proposed. This carries forward a long tradition of populist sentiment and political pledges for low fares since the time of William Randolf Hearst.[10]

Outside sources of funding are becoming more difficult to find. The federal operating subsidy, which gave the MTA $122 million this past year, is expected to decline, if not disappear altogether, under President Reagan's budget cuts. This, despite the recent 5 cent gasoline tax which will give $1.1 billion to transit subsidies nationwide but is expected to go to capital projects rather than operating expenses. The state, which recently contributed $107 million to the subsidy, is unlikely to continue to increase its contribution because legislators from outside the MTA commuting territory are not convinced that their constituents should subsidize New York City.

This means that New York City and the riders themselves will be the major source of revenue for the MTA--either in the form of higher fares or higher taxes that could come from a variety of sources (personal income, property and various corporate excises are all used at this time to fund the City and region's

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9 Kenneth M. Chomitz and Charles A. Lave, "Part-Time Labor, Work Rules, and Transit Costs," University of California, Irvine, January 1981.

10 See Derrick.

contribution). Subsidies from the region now total \$329 million and more will be forthcoming as the State legislature recently passed a tax package to "save" the 75-cent fare. The battle to get these tax increases was long, exhausting and bitter. It showed that the City was adamantly opposed to increasing its share of the subsidy by taking funds from other City budgets.

Another source of revenue is various charges to motor vehicle users. These can include new or increased gasoline taxes and tolls on the region's bridges, tunnels and highways. Governor Carey proposed such bridge toll subsidies as a way of funding capital expenditures. Already the MTA gets a transfer from the Triborough Bridge and Tunnel Authority in the amount of \$92 million. Also, the Port Authority of New York and New Jersey runs its subway at a loss suggesting a cross-subsidy from its bridges and tunnels.[11] Raising gasoline taxes and tolls are not politically popular. The Canadian government was recently voted out of office partly because it advocated higher gasoline taxes. New York legislators attached a provision to the 1977 Clean Air Act Amendments effectively prohibiting toll increases as a transportation control strategy.[12]

It is worthwhile to insert a note about fare structure as opposed to fare level. The MTA currently uses a flat fare of 75 cents. This is the price of a trip regardless of its length or time of day. Various commentators have noted that such a fare structure leads to inefficiencies: overcrowding of the peak and higher subsidies for people taking long trips as opposed to short trips. It is quite possible that rationalizing the fare would save money for the MTA. This would involve

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11 The Port Authority of New York and New Jersey, 1980 Annual Report (New York: April 9, 1981), p. 30.

12 U.S. Environmental Protection Agency, "Evaluation of the State Implementation Plan Revision Submitted by New York State in Fulfillment of the Moynihan-Holtzman Amendment," EPA 902/4-79-004, a report by Alain L. Kornhauser Associates, September 1979, p. 1 ("Kornhauser").

relating fares to the cost of service and to the demand at various times of day--specifically, charging higher fares for long trips and for peak-hour trips than for short and/or off-peak trips. This would, however, be a one-shot saving. It does not solve the problem of continual cost increases outstripping overall fare increases.

In summary, we are left with only a few strategies to combat cost increases, and all are painful. First, it can increase fares. Second, the MTA can let the plant and service continue to deteriorate. Third, it can try to get subsidies from motorists through increased bridge and tunnel tolls. Finally, it can try to get increased subsidies from the region's general tax coffers.

Any strategy will have adverse effects on New York City. Worse service or higher fares makes the City, especially the CBD, a less attractive destination for workers, shoppers, theater-goers, etc. As employment, retail trade and other services migrate out of the city, ridership declines setting in motion another round of fare increases and transit cutbacks. The cycle continues to the detriment of riders and the Manhattan economy. Economic decline also means tax losses to the City government.

In the pages which follow, we explain how these effects can be measured, at least approximately.

III. ESTIMATES OF THE EFFECTS OF INCREASED POWER COSTS

The approach I have used in estimating the effects of increased power costs consists of the following steps:

A. The fare increase required to cover the MTA's larger power bill is computed. This fare increase has two components: first, is the amount of revenue needed to pay for increased electricity charges; second, is an increase in fare needed to compensate the MTA for riders lost from the original fare hike. Aggregate ridership declines are computed as part of this step.

B. The effects on employment are then estimated by determining how a transit fare increase would affect the supply and demand for labor in New York City. The effects on income and city tax revenues are made proportional to the lost jobs in the City.

C. Under the alternative assumption that the MTA reduces service in response to increased power costs, the increase in travel time for tripmakers is estimated. This is then used to compute lost ridership and step (B) is repeated.

Each of these steps, and the results, are described in the sections which follow.

A. Effect of Higher Power Costs on MTA Fares and Ridership

The most likely strategy to be used by the MTA in paying for higher electricity bills is to increase its fare. The amount of the fare increase will depend on two factors: first, the extra revenue required to cover the cost of power; second, the increase in fare required to compensate the MTA for riders which are lost as a result of increased prices. The first factor is rather obvious; the second, however, requires further explanation.

As the MTA raises its fare, it will lose ridership. An increase in the price of transit will cause tripmakers to make a series of adjustments including travel by competitive modes (e.g., taxi, auto and walking) and, in some cases, fewer trips altogether. In the long run, transit costs affect other decisions which also reduce travel. These include the location of households, employers, retailers and personal services all of whom take into account transportation factors (as well as many other things) in their decisions about where to locate. As travel by transit becomes more costly or onerous, these households and enterprises will attempt to conserve on transit use by themselves, their employees and their patrons.

A convenient measure of the sensitivity of travelers to fare increases is the price elasticity of transit demand. Though the computation of elasticity of demand will differ depending on the circumstances of its use, it can be approximated with the following formula:

$$\text{transit fare elasticity} = \frac{\text{percent change in transit trips}}{\text{percent change in fare}}$$

For example, if a 100 percent fare increase causes a 20 percent reduction in transit ridership, then the elasticity is equal to -.20 (=-20/100).

The elasticity of demand for urban travel has been studied extensively over the past twenty years. In fact, a number of these studies have focused on New York City. These studies are reviewed in Attachment Two. One conclusion which emerges is that there is a reasonable consensus about short run transit fare elasticities. Alternatively, none of the existing studies of New York City estimated long run transit fare elasticities. For my purposes, this is a critical gap because the economic effects of transit fare changes are clearly long run in nature.

My solution to this problem was to estimate an econometric model, described in Attachment Two, which is used to derive transit demand elasticities for New York City. Two equations in this model estimate the demand for bus and

subway travel in New York City; in each case, demand depends on a number of factors including transit fare and New York City employment. Two other equations show how New York City employment is affected by transit fares. As shown in Attachment Two the estimates of the long run elasticities of transit ridership, taking into account the effects of higher fares on employment in New York City, are as follows:

long run fare elasticity of subway demand = - 330

long run fare elasticity of bus demand = -.4

These estimates appear to be supportable fro the existing literature (reviewed in Attachment Two) and from the statistical tests used to determine the reasonableness of econometric models.

Let me return to my initial objective of determining the effect of power cost increases on fare levels. The relevant formula to be used in this computation is as follows:[13]

$$\text{percent increase in fare} = \text{percent increase in required revenue} \times \frac{1}{1 + \text{fare elasticity of transit demand}}$$

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13 This formula can be derived by noting the following relationships:

percent change in revenue = percent change in fare + percent change in ridership

and

percent change in ridership = (percent change in fare) x (elasticity)

therefore

percent change in revenue = (percent change in fare) x (1 + elasticity)

It should be noted that this formula assumes that the MTA will not cut costs in response to a decline in demand. This is a reasonable assumption. As shown on pp. 16-20, infra., such attempts would be self-defeating because they would cause the MTA and the City to lose more revenue (combined) than they would save in costs.

As can be seen, to determine the required increase in fare, we need to know, first, the increase in required revenue and, second, the fare elasticity of overall transit demand.

The increase in revenue will simply be equal to the increase in power costs. I am advised that the Power Authority will be forced to increase its electricity rates to the MTA by 29.5 percent if Indian Point is taken out of service.[14] Using the MTA's estimated current power costs of $148.6 million, this would mean an increase of $43.8 million (=.295 x 148.6) for electricity. To pay for this extra expense out of fares will require a 5.03 percent increase in revenues from this source (see Table 1).

A question arises as to whether the MTA would increase fares on only its subway operations or whether it would increase fares on both subway and bus to recover these costs. It has been longstanding MTA policy to charge the same base fare on both subway and bus. Consequently, I make the assumption that fares on both subway and bus would increase in like amounts.

Under this assumption, the relevant elasticity would be that which measures the demand response for both subway and bus combined. This is simply a weighted average of the separate subway and bus elasticities where weights are proportional to ridership on each mode. Using 1980 as a base year, 63 percent of the MTA's ridership was on subways and 37 percent was on buses.[15] The system average long run elasticity is equal to -.371 (=-.330 x .63 -.440 x .37).

The fare increase caused by higher power costs can now be computed. Using the aforementioned formula,

$$\text{percent increase in fare} = 5.03\% \times \frac{1}{1 - .371} = 8.00\%$$

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14 See Testimony of Sally Streiter. This is the average for the years 1984 through 1986 which is the period of employment and income forecasts used in this analysis

15 Annual Report, p. 23.

Using the current base fare of 75 cents, this means that the fare would have to increase by 6 cents a ride to cover the higher costs of electricity.

At this higher fare level, there would obviously be fewer riders. The elasticity of demand can be used to determine the ridership decline. Specifically, there would be 2.97 percent fewer transit trips (= .371 x 8.00%).

B. Decline in Employment and Economic Activity

The next step in the analysis is to translate higher fares into lower employment in New York City. As mentioned before, there are a series of economic adjustments which will be made to higher transit costs. These will include a number of adjustments which reduce economic activity in New York City. Commonly cited examples of such long term adjustments include the following:

1. Retail Sales, Entertainment and Other Personal Services. As transit travel becomes more expensive, New York City becomes less competitive for consumers' dollars. As a result, employment in these sectors will decline.[16]

2. Place of Work. Employers are sensitive to transportation costs in their location decisions. Transit costs affect the size of the labor force from which an employer can draw as well as the wage demands of employees.[17] Employees will also be affected by transit in deciding where they will work.

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16 An empirical analysis of how transportation level of service affects retail sales in downtown Denver is given in Clifford R. Kern and Steven R. Lerman, "Models for Predicting the Impact of Transportation Policies on Retail Activity," prepared for the Annual Meeting of the Transportation Research Board, January 1978.

17 These adjustments are described in more detail in Daniel E. Chall, "The Economic Costs of Subway Deterioration," Quarterly Review, Federal Reserve Bank of New York, Spring 1981 ("Chall").

3. Household Location. Finally, transit fares affect the cost-of-living in New York City. This is a factor in considering the attractiveness of New York City as a residence. Though transit will rarely be an overriding factor, it can certainly contribute to household location decisions.

Though all of these effects are well recognized, they are exceedingly difficult to measure with precision. When called upon to do so, transit planners use large, complex and highly disaggregated computer models which simulate the many interactions between an urban economy and the transportation system.

The approach used in this study is more aggregated. Specifically, the model in Attachment Two includes New York City labor supply and demand equations which have transit fare as one of the variables affecting employment. The estimates presented in Attachment Two show that each percent increase in transit fare causes New York City employment to decline .04 percent. This means that the transit fare increases caused by higher electricity costs would, in turn, cause employment in New York City to drop by .32 percent (= 8.00 x .04). It should be noted that these employment effects exclude the impacts of higher commuter rail fares. Because a shutdown of Indian Point will also increase the costs of commuter rail service, it can be presumed that the economic impacts estimated below are understated.

Forecasts of New York City employment (and income) to 1986 are available from the Mayor's Budget Office. These are presented in Table 3. Using 1986 as a reasonable long run forecast year, the predicted employment in the City is 3,548.5 thousand. A reduction of .32 percent would mean 11.4 thousand lost jobs.

The decline in New York City aggregate personal income and tax revenues is made proportional to the decline in employment. Forecasts of these

are also presented in Table 3. Again using 1986 as the forecast year, the result is that income would decline by $323 million and city tax revenues would decline by $34 million.

C. Effects of Paying for Increased Power Costs by Reducing Service

Though I believe the MTA would probably raise transit fares to pay for increased power costs, it is not certain that they would be able to do this in the face of political, and possibly public, opposition. Consequently, it cannot be dismissed that the MTA would attempt to keep fares constant and conserve on other costs as a means of getting enough money to pay for higher electricity bills. This would mean further deterioration of plant and vehicles (deferred maintenance) as well as reduced bus and subway service.

Reducing transit level of service has a greater impact on ridership than does increasing fares.[18] Specifically, it is a well-known result that transit travel demand is more responsive to changes in trip time than changes in price. The results presented below verify this conventional viewpoint.

To estimate the effects of reducing service, I have used a variety of studies available from the New York State Metropolitan Transportation Council (formerly the Tri-State Regional Planning Commission). Specifically, these allow me to do the following:

1. Determine how a one percent decline in the funds available for transit operations affect the average travel time for work and nonwork tripmakers;
2. Determine the decline in transit travel from the estimated increase in travel time caused by the power cost increase.

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18 See, generally, Thomas A. Domencich and Gerald Kraft, Free Transit, (Charles River Associates, Cambridge, MA: 1970).

To estimate the long run employment effects, I assume that these lost transit trips are related to New York City employment as if they had been caused by an increase in transit fare. These steps, and their results, are described below.

1. Effect of Increased Power Costs on Average Trip Time

There are a number of ways which the MTA can attempt to save costs as a result of having to pay for higher electricity bills. Typically, the first service to decline would be in the off-peak where trains, and possibly buses, would be cut back in an effort to increase load factors. There would also be shorter trains creating more crowded conditions. These schedule changes would also reduce co-ordination between bus and subway which would increase transfer time.

Changes of this type in MTA services were recently analyzed by Tri-State. In terms of transit time improvements, the results of this study are summarized in Table 4. Basically, the authors found that an increase in MTA expenditures of \$22 million would cause average work trip time savings of 1.98 percent and average nonwork trip time savings of about 3.96 percent. Total expenses for the transit system were \$1,108 million in the fiscal year ending June 1977--the year of the Tri-State study.[19] Thus, the improvements causing these trip time savings would impose cost increases of 1.99 percent. In the results presented below, I make the reasonable assumption that this relationship is symmetric. That is, a 1.99 decrease in operating funds causes a 1.98 and 3.96 percent increase for work trip travel time and nonwork trip travel time respectively.

The increase in power costs caused by shutting down Indian Point at this time would cause 2.20 percent of MTA operating costs to be transferred.

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19 Annual Report, p. 27.

Assuming that the effects on travel time are proportional to the cost declines, then the effect on average travel times would be as follows: transit work trip time would increase by 2.19 percent and transit nonwork trip time would increase by 4.38 percent. These are significant changes in level of service for MTA patrons, as will be shown below when we compute the effects on ridership.

2. Effect of Lower Level of Service on Ridership

The sensitivity of transit demand to level of service has been studied intensively for many years with the result that there is a reasonable amount of agreement about how these factors influence demand.[20] A commonly used (but by no means the only) measure of ridership response to changes in trip time is the elasticity of travel demand with respect to time. This elasticity is defined, analogously to the fare elasticity, as follows:

$$\text{transit travel time elasticity of demand} = \frac{\text{percent change in ridership}}{\text{percent change in travel time}}$$

As with the fare elasticity, this elasticity will be higher in the long-run than in the short-run. Also, there is substantial evidence that this elasticity is higher for out-of-vehicle time (e.g., for waiting at transit stops and transferring) than for in-vehicle time. There is less evidence for the notion that the elasticity would be higher as transit becomes more uncomfortable (e.g., through overcrowding and lack of air conditioning) though common sense would suggest this to be true.

The estimates of this elasticity which I use do not take all of these nuances into account. I start with short run elasticities, estimated by Tri-State,

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20 See, for example, Armando M. Lago, Patrick Mayworm and J. Matthew McEnroe, "Transit Service Elasticities," Journal of Transport Economics and Policy, May 1981, pp. 99-119.

which are as follows:[21]

work trip transit time elasticity = -0.50

nonwork trip transit time elasticity = -0.55

These values can be aggregated into a total system elasticity by noting that 65 percent of transit ridership is for work trips and 35 percent is for nonwork travel.[22] Thus, the short run transit time elasticity for all purposes combined is -.518 (= -.50 x .65 -.55 x .35).

As in the case of the transit fare analysis, it is appropriate to use long run (rather than short run) elasticities to determine the long run economic effects of transit service deterioration. It is reasonable to assume that the ratio of long run to short run transit time elasticities is the same as the ratio of long run to short run transit fare elasticities. This ratio as derived from the econometric models of transit ridership in Attachment Two is equal to 1.444. Therefore, my estimate of the long run elasticity of transit ridership with respect to travel time is -.748 (- .518 x 1.444).

Ridership losses from reducing the level of service to cope with higher power costs can be computed from this elasticity. First note that the weighted average increase in travel time is 2.96 percent per trip (= .65 x 2.19 + .35 x 4.38). Consequently, the MTA would lose 2.21 percent (= 2.96 x .748) of its passengers if travel time increased by this amount.

However, this is only the first-round effect. Clearly, ridership declines reduce the MTA's fare box revenues and increase the operating deficit.

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21 See ITR 2121, pp. 26-27 and Tri-State Regional Planning Commission, "Interim Technical Report 5303: Short Term Effects of Transportation Policy Changes on Auto and Transit Ridership," (New York: August 1977), pp. B-7--B-8.

22 Tri-State Regional Planning Commission, The Effects of Fare Changes on Public Transportation Ridership and Revenues, March 1980, Appendix B.

Thus, the MTA would have to take further cost-cutting measures to protect the fare. The magnitude of these measures can be gained by noting that farebox revenues contribute 43.69 percent to the MTA's operating costs (see Table 1). Therefore, the operating deficit as a percentage of operating costs caused by the lost ridership is .97 percent (=.4369 x 2.21).

Consequently, for every 2.20 percent cost-cut, the MTA loses a .97 percent contribution to cost from the farebox. Stated another way, if the MTA saves $2.20 from cutting service, it will lose $.97 in revenue. This means that to close its deficit from lost ridership without raising fares, it has to decrease costs (and service) even more than the original 2.20 percent reduction. In fε the eventual reduction in costs would be 5.07 percent.[23] This, in turn, causes a increase in average trip time of 5.30 percent (= 2.96 x 3.93/2.20) and a total loss in ridership of 3.96 percent (= 5.30 x .748).

3. Effects on Economic Activity in New York City

As with the case when fares increase, lost ridership for service

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23 The mathematics which produces this result is as follows:

cost = revenue

after the shutdown at Indian Point, cost increases by 2.20 percent and revenue decreases by (.97/2.20) x change in cost. In order to keep revenue equal to cost:

$$(1.0220 + \frac{\text{change in cost}}{\text{cost}})\ \text{cost} = (\frac{\text{change in revenue}}{\text{cost}} + 1)\ \text{cost}$$

which can be solved for the eventual cost increase as follows:

$$\frac{\text{change in cost}}{\text{cost}} = -.0220/(1-.97/2.20)$$

$$= -.0393$$

or 3.93 percent.

deterioration signals long run employment declines for New York City.[24] It would seem reasonable that the ratio of employment loss caused by reduced transit service to employment loss caused by higher fares is equal to the ratio of riders lost from reduced service to riders lost from higher fares. The effect of a fare increase was estimated above to cause a 2.97 percent decline in transit riders and a .32 percent decline in employment. Correspondingly, the 3.96 percent decline in ridership caused by reduced service would be associated with a 0.43 percent decline in employment (= 3.96 x .32/2.97).

Using this percentage reduction for 1986 predicted employment (in Table 3) gives an estimate of 15.3 thousand jobs lost to the City. Applying this proportionate decline in employment to 1986 personal income (see Table 3) would result in a loss of aggregate personal income of $434 million. Similarly, New York City tax revenues would decline by $46 million.

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24 See Chall.

TABLE 1

NEW YORK CITY TRANSIT AUTHORITY
RECOMMENDED OPERATING BUDGET FOR FISCAL YEAR 1981-82

	Fiscal Year 1981-82 Recommended Operating Budget (Millions of Dollars)
Revenues and Subsidies	
Fare Box	870.0
Non-Fare Box	16.6
City Appropriation	328.9
State Assistance	106.7
Federal Assistance	122.2
Oil Company Tax	103.5
T.B.T.A. Transfer	92.0
Total-Revenues and Subsidies	1,639.9
Expenses	
Salaries and Wages	1,033.9
Fringe Benefits	357.6
Transit Authority Police	127.7
Power Purchased	148.6
Fuel for Buses	41.9
Materials and Supplies	183.9
Rentals and Miscellaneous	89.0
Provisions for Public Liability	26.7
Contingency Fund	75.0
Capital Engineering	36.0
Debt Service	10.6
Reimbursements	(139.7)
Total-Expenses	1,991.2
Operating Results	
Surplus	(351.3)
Cash Flow Adjustment	27.8
Cash Increase	(323.5)
Cash Balance, Including Working Capital	
Opening Balance	(33.6)
Closing Balance	(357.1)

Source: New York City Transit Authority-- System, 1980-81 Forecast and 1981-82 Recommended Operating Budget, obtained through Harvey Poris, of the New York City Transit Authority Budget Office, (212) 330-3570.

TABLE 2

SUMMARY OF TRI-STATE (NEW YORK CITY) REGION PUBLIC TRANSPORTATION FINANCES IN 1968 AND 1981

		1968	1981	Percent Change $\frac{(2)-(1)}{(1)} \times 100$
		(1)	(2)	(3)
(1)	Annual Person Trips (million)	2,834	2,138	-25%
	Revenues:			
(2)	Farebox (millions of dollars)	\$ 752	\$1,604	113%
(3)	Other (millions of dollars)	\$ 70	\$ 253	261%
(4)	Total Revenue (millions of dollars)	\$ 822	\$1,857	126%
(5)	Operating Expenses: (millions of dollars)	\$ 919	\$3,679	300%
(6)	Operating Deficit (millions of dollars) (5)-(4)	\$ 97	\$1,822	1,778%
(7)	Farebox Revenue per Trip (dollars) (2) (1)	\$ .27	\$ .75	178%
(8)	Operating Expenses per Trip (dollars) (5) (1)	\$ .32	\$ 1.72	438%
(9)	New York City Consumer Price Index	104.3	259.9	149%

Source:

Rows (1)-(5): Tri-State Regional Planning Commission, The Effects of Fare Changes on Public Transportation Ridership and Revenues (New York, NY: March 1980), pp. A-1, A-2, A-3, and A-4; and Tri-State Regional Planning Commission, Annual Transportation Report (New York, NY: June 1982), p. vi.

Row (9): U. S. Department of Labor, Bureau of Labor Statistics, Handbook of Labor Statistics, (Washington, D.C.: U. S. Government Printing Office, December 1980), p. 332; and U. S. Department of Labor, Bureau of Labor Statistics, CPI Detailed Report, January 1982, (Washington, D.C.: U. S. Government Printing Office), p. 111.

TABLE 3

FORECASTED NEW YORK CITY PERSONAL INCOME, EMPLOYMENT AND LOCAL TAX REVENUES

1983 - 1986

	Year			
	1983	1984	1985	1986
	(1)	(2)	(3)	(4)
Total Personal Income[1] ($ Millions)	93,900.00	96,700.00	99,100.00	101,000.00
Total Employment (Thousands)	3,390.70	3,451.90	3,492.20	3,548.50
Total City Funds[1] ($ Millions)	10,784.00	10,676.00	10,693.00	10,640.00

[1]1983 dollars.

Source: "Message of the Mayor," The City of New York Executive Budget, Fiscal Year 1983, pp. 15 and 51.

IMPROVEMENT IN AVERAGE TRANSIT TRIP TIME CAUSED BY $22 MILLION IN SERVICE UPGRADING EXPENDITURES [1]

County	Proportion of Transit Trips	Work Trip Travel Time Savings		Nonwork Trip Travel Time Savings	
		Unweighted (Percent)	Weighted (Percent) (1)x(2)	Unweighted (Percent)	Weighted (Percent) (1)x(4)
	(1)	(2)	(3)	(4)	(5)
N.Y. (CBD)	.252	0.0	0.000	4.1	1.033
N.Y. (No. of 60th)	.170	2.7	0.459	2.7	0.459
Bronx	.130	1.8	0.234	3.6	0.468
Kings	.226	1.9	0.429	3.8	0.859
Queens	.202	3.6	0.727	5.5	1.111
Richmond	.020	6.4	0.128	1.3	0.026
Total	1.000	NA	1.977	NA	3.956

[1] Expenditures are tabulated by type on p. 33 in the source cited below.

Source: Tri-State Regional Planning Commission, "The B-5 Strategy" Interim Technical Report 2121 (New York: July 1977).
Column (1), p. 15.
Column (2), p. 22.
Column (4), p. 23.

ATTACHMENT ONE

VITA

VITA

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DATE OF BIRTH: May 1, 1944

BUSINESS ADDRESS:

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EDUCATION:

TUFTS UNIVERSITY
Ph.D., Economics, 1971
Dissertation Subject: Stochastic and Optimal Control Models of Income Distribution

TUFTS UNIVERSITY
M.A., Economics, 1969

REED COLLEGE
B.A., Mathematics and Economics, 1966

EMPLOYMENT:

NATIONAL ECONOMIC RESEARCH ASSOCIATES, INC.

1979-1983 Senior Consultant. Directs projects in the economics of antitrust, transportation, energy, and the environment.

CHARLES RIVER ASSOCIATES, INC.--Boston, Massachusetts

1976-1979 Program Manager. Responsible for studies in transportation, urban development, and various fuels; director of CRA's subsidiary, Econometric Appraisal Systems, Inc.

1971-1976 Senior Research Associate. Performed studies on the coal, metals, and computer industries.

NORTHEASTERN UNIVERSITY--Boston, Massachusetts

1969-1971 Instructor, Department of Economics. Taught graduate courses in mathematical economics, econometrics, and statistics; taught undergraduate courses in macroeconomics, business cycles and growth, and advanced statistics.

TUFTS UNIVERSITY--Medford, Massachusetts

1969 Instructor, Department of Economics. Taught social control of industry.

AWARDS AND PROFESSIONAL ACTIVITIES:

National Science Foundation Trainee, Tufts University, three-year grant.

Kennedy Memorial Teaching Award, Tufts University.

Reviewer for Transportation Research Forum, Transportation Research Record and Journal of Industrial Economics.

Member, Transportation Research Board, National Academy of Sciences, Subcommittees on Research Needs, Spatial Choice, Transportation Energy, and 1980 Subcommittee Chairman on Telecommunications in Urban Freight Movement.

Advanced Transit Association. Member of the Nominating Committee for Directors and Officers.

American Marketing Association. Co-host of American Marketing Association Workshop: Marketing Public Transportation, 1979.

American Economic Association

International Association of Energy Economists

Transportation Research Forum

Chairman of the Board, Boston Arts Group, 1979

INVITED AND REFERRED PUBLICATIONS:

With L. Perl, "Mineral Sales Agreements--Indexing Coal and Other Mineral Contracts." Eastern Mineral Law Foundation, Third Annual Institute (1982).

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Measurement of the Effects of Transportation Changes. Washington, D.C.: Urban Mass Transportation Administration, Department of Transportation, 1972.

TESTIMONY, SPEECHES AND CONSULTING REPORTS:

Testimony before the State of New York, Department of Agriculture and Markets, on competition in New York milk markets, on behalf of Mesmer and Sons Dairy, Inc., 1982

"Remarks on the Pros and Cons of Rail Rate Deregulation to Captive Shippers," presented at the New York Chapter, Transportation Research Forum, 1982. (Reprinted in Cargo, Los Angeles Commercial News, Section Two, February 28, 1983.)

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ATTACHMENT TWO

ESTIMATES OF NEW YORK CITY TRANSIT DEMAND ELASTICITIES

This attachment presents the econometric model which was used to estimate the transit demand elasticities in my Testimony. The first part of the Attachment describes prior research on urban travel demand elasticities. This review of the literature is used to check the reasonableness of the econometric results presented in the following sections. These econometric results are presented in two parts: first, the equations which estimate subway and bus demand; second, the equations which estimate the supply and demand for labor in New York City.

I. PRIOR RESEARCH ON URBAN TRAVEL DEMAND ELASTICITIES

In reviewing the literature, it is useful to divide the prior research on travel demand into two categories: first are studies of New York City travel behavior; second are more general studies of travel behavior in a number of other large cities with rapid transit systems. As will be shown below, this latter category offers insights into long run travel demand, which is a gap in New York City specific transit research.

A. Studies of New York City Transit Demand

The New York City transit system has been the subject of several studies of travel demand. The three most recent efforts made econometric estimates from time-series data, which is also the approach we have used. Two earlier studies used the before-and-after method; that is, ridership was measured before a fare increase and then was measured afterwards to determine the short run traveler response. In addition, there have been several reviews of existing studies in an attempt to derive transit demand elasticities.

The results of this research are summarized in Table 2-1. As can be seen, the most recent studies (spanning 1977 through 1981) estimate a short run subway elasticity in close proximity of each other--from -.11 to -.20. Earlier

studies (including Lassow and those reviewed by Pucher-Rothenberg) resulted in a greater range of estimates--from -.08 to -.25. It should be noted that the recent Environmental Impact Statement for the proposed 75-cent fare assumed an elasticity of -.23 (Hart), but there is no data in the statement to support this estimate. Our estimate of short run subway elasticity, by comparison, is -.238. Though this is somewhat higher than the others, it is not overly so and can be easily explained by noting that the fares over our period of observation were higher than in the other studies.

These studies have consistently found the bus elasticity to be greater than the subway elasticity. This was also found in our research. Three studies of bus elasticity (Finch, Obinani and Lassow) produced estimates which were slightly greater than ours--their elasticities are in the range of -.32 to -.36 whereas our estimate is -.288. Alternatively, Pucher-Rothenberg reviewed studies which estimated bus elasticities as low as -.16. Though these are not overly large differences in values, they do show that bus elasticity estimates are somewhat sensitive to the specification of travel demand models and, possibly, the time period over which the model is estimated.

B. Results from Travel Demand Models

Given the absence of information on long run transit elasticities for New York City, it is useful to review several studies of travel demand from outside the region. There is a large literature on travel demand and a large number of studies on traveler response to transit fare changes. However, I wish to focus on a relatively small number of these studies. Specifically, I will only review those studies which estimated travel demand models on cross-section data from cities with rapid transit systems.

There are two reasons for restricting my focus. The first is obvious: cities with rapid transit systems are more like New York than cities without rapid transit. The second reason is more subtle. Generally, models of travel demand estimated with cross-section data result in elasticities which are substantially higher than elasticities estimated from either time-series data or before-and-after studies. I have analyzed this phenomenon and concluded that the reason for this is that cross-section models actually estimate a mixture of long run and short run behavioral responses.[1]

The results of various studies are summarized in Table 2-2. This table presents the estimates of various transit fare elasticities from two recent reviews (Pucher-Rothenberg and Chan-Ou) as well as one earlier model (Domencich-Kraft). Let me focus initially on the early model of Domencich-Kraft which was estimated on 1963 interzonal travel data from Boston. The results of this model became the standard by which the estimates of later models were compared. As can be seen, the model produced elasticities of -.09 for work trips and -.323 for shopping trips.

Virtually all other models estimated higher transit demand elasticities. One such model, Talvitie's, used the same approach as Domencich-Kraft but was based on Chicago data. As can be seen, Talvitie estimated a subway work trip elasticity of -.51 and bus work trip elasticity of -1.8. These estimates are 5 to 20 times higher than the Boston study. Another study of note is McFadden's disaggregate demand model of San Francisco. Unlike the other studies, McFadden constrains the total number of work trips to be constant; therefore, his elasticity is

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1 See Frederick C. Dunbar, "Use of Before-and-After Data to Improve Travel Forecasting Methods," Transportation Research Record 723 (1979), pp. 39-45 and Policy Evaluation with Travel Behavior Models for the U.S. Department of Transportation DOT-P-30-79-14, April 1979, Chapter 1.

possibly an underestimate of the true long run value becꞇ se, presumably, he is not counting any employment declines in his effects. Even so, his estimates are 6 to 10 times higher than the original Domencich-Kraft study and are in the general range of Talvitie's estimates.

The remaining data come from a large number of comparable studies reviewed by Pucher-Rothenberg and Chan-Ou. Rather than present the individual estimates from each of the studies reviewed, I have presented the range of estimates reported. In general, these estimates tend to be higher than either the short run elasticities from New York or the (arguably) long run elasticities from Domencich-Kraft.

It will be recalled that our estimate of long run elasticity was -.330 for subways and -.440 for bus. These imply a long run system elasticity of -.371. How do these estimates compare? Our long run subway elasticity is in the lower end of the range of other estimates. This is to be expected because New York City has a much higher percentage of total travel by subway than do other cities. Consequently, there are fewer alternatives for New York subway riders in response to a fare increase. Both long-run bus elasticity and overall system elasticity are also in the lower part of the range among those estimated--again, probably for the same reason.

In general, it can be concluded that our demand equations--described in the following section--are giving results which are consistent with prior research.

II. ESTIMATES OF TRANSIT FARE ELASTICITIES

This section is divided into three parts on the following topics: first, the transit demand relationships which are used to compute long run elasticities; second, the econometric estimates of transit demand equations; third, the computation of long run elasticities from the econometric estimates of transit demand and employment effects (the equations which predict employment effects are presented in a following section).

A. Transit Demand

The model of transit demand used in this study is somewhat more elaborate than the other models for New York City cited in Section I. The reason for this is that I am primarily interested in determining long run transit effects whereas the other models focus on short run behavior. To explain the model, let me derive it in stages, first starting with a short run model and then expanding it to include long run effects.

The simplest model of transit demand can be expressed as follows:

(1) $TR = b_0 + b_1 TF$

where:

TR	=	transit ridership
TF	=	transit fare
b_0, b_1	=	parameters

This model states that ridership in the current period is a linear function of fare in the current period. Though this equation may have a certain amount of explanatory power, there are several extensions which make it more realistic. Among these is the notion that current ridership is a function of other factors. For example, I have postulated that the long run fare elasticity is greater

than the short run fare elasticity. This means that the fare in previous years will have an effect on current ridership in addition to the effect of the current fare. In symbols, this means that equation (1) should be expanded as follows:

$$(2)\ TR = b_0 + b_1 TF + b_2 TF(-1) + b_3 TF(-2) + \ldots$$

where: X (-i) means that the variable X has been lagged i years.

Unfortunately, an econometric estimate of an equation of this form would be unreliable because the lagged values of the independent variables are highly multicollinear. The most common approach to solving this problem is to impose a simplifying assumption on the relationship between coefficients. Specifically, it seems reasonable to suppose that the effect of fare levels in prior years is less than the effect in the current year. If we make the further assumption that the effect declines geometrically, then

$$b2 = kb_1,\ b_3 = k^2 b_1,\ b_4 = k^3 b_1, \ldots$$

where k is less than one and greater than zero.[2]

Let us also presume that the demand relationship is log-linear in specification. Then, the demand function has the following form:

$$(3)\ \ln TR = b_0 + b_1 \ln TF + kb_1 \ln TF(-1) + k^2 b_1 \ln TF(-2) + \ldots$$

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2 This is a Koyck lag, which was named after its developer. The approach is described in standard econometric texts including Henri Theil, Principles of Econometrics (New York: John Wiley & Sons, Inc., 1971), pp. 258-263 and J. Johnston, Econometric Methods, Second Edition (New York: McGraw-Hill Book Company, 1972), pp. 298-303.

The long run elasticity of demand (NL) with respect to a once and for all change in transit fare is then:

$$(4)\quad NL = b_1(1 + k + k^2 + \ldots)$$

Equation (4) makes use of the well-known result that the coefficients of a log-linear demand function are themselves elasticities.[3] Equation (4) contains a declining geometric series which has a similarly well-known sum. Specifically:

$$\frac{1}{1-k} = 1 + k + k^2 + \ldots$$

This means that the long run elasticity has the following formula:

$$(5)\quad NL = \frac{b_1}{1-k}$$

The advantage of equation (3) is that it can be estimated easily with a simple transformation. This transformation makes use of the demand equation from the previous period multiplied by k:

$$(6)\quad k\ln TR(-1) = kb_0 + kb_1 \ln TF(-1) + k^2 b_1 \ln TF(-2) + \ldots$$

Subtracting equation (6) from equation (3) results in a demand model as follows:

$$(7)\quad \ln TR = (1-k)b_0 + b_1 \ln TF + k \ln TR(-1)$$

---

3 To see this, consider the relationship

$\ln Y = a + b \ln X$. Then $b = \frac{d\ln Y}{d\ln X} = \frac{\text{percent change in } Y}{\text{percent change in } X}$

which is the definition of elasticity.

This equation has fewer parameters to estimate than does equation (3). Nonetheless, some care must be taken in estimating equations with lagged dependent variables (as is the type represented by equation (7)) because the conditions under which ordinary least squares (OLS) gives good estimates of b_1 and k can be violated; the methods used to correct this problem are described below when the econometric estimates are presented.

Another issue of specific concern is the relationship among employment, transit fare and transit ridership. There are two considerations: first, current transit ridership is attracted by the level of employment in the City; second, historical levels of transit fare affect both the supply and demand for labor in the City. To account for the first consideration, equation (7) should be modified to include employment (E) as follows:

$$(8)\quad \ln TR \quad = \quad (1-k)b_0 + b_1 \ln TF + b_2 \ln E + k \ln TR(-1)$$

This change in the equation also changes the computation of the long run elasticity. The reason for this is that employment is affected by lagged values of transit fare. In Section III below, this effect is quantified with equations representing the New York City labor market. Econometric estimates of the parameters in these equations are used to compute the elasticity of employment with respect to transit fare where

$$NE = \frac{d\ln E}{d\ln TF(-1)}$$

Thus the long run effects on transit ridership from a fare increase are separated into two categories: ridership declines holding employment constant; and ridership declines caused by employment declines which were, in turn, caused

by the fare increase. In symbols, the long run transit elasticity is computed as follows:

$$(9)\ NL = \frac{b_1 + b_2 NE}{1-k}$$

The econometric estimates of transit demand described below are used to compute b_1 (the short run transit fare elasticity), b_2 (the elasticity of transit demand with respect to employment), and k (called the adjustment speed in Koyck lag terminology).

Two other modifications to equation (8) have been made in order to improve the accuracy of these coefficient estimates. First, a number of other factors affecting transit demand have been added to the equation; these variables do not affect the computation of long run elasticity described by equation (9). Second, subway and bus demand equations are estimated separately, again to improve the accuracy of the estimate of the overall system elasticity.

B. Econometric Estimates of Subway and Bus Demand

The data used to estimate subway and bus demand equations are monthly observations of ridership over the past decade. The independent variables in these equations are defined in Table 2-4 and incl de, as noted in the previous section, transit fare, employment, and subway or bus ridership lagged twelve months. In addition, I have included several other exogenous influences on monthly transit ridership such as number of workdays per month, transit level of service (e.g., vehicle failure rate and vehicle-miles in service) and a variety of dummy variables representing either off-peak fare policy or extraordinary disruptions (e.g., strikes and blizzards).

The regression estimates are presented in Table 2-3.[4] In evaluating

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4 The software employed for estimating these regressions was SAS (Statistical Analysis System) which is commonly used in econometric analysis.

these results, it is worthwhile to first discuss several statistical issues and then the individual parameter estimates.

With regard to statistical methods and specification, there are four important topics: first, exogenous variables which have been omitted from the equations; second, the evidence on long run versus short run elasticities; third, the statistical problems caused by including the lagged dependent variable; and, fourth, the codetermination of employment and transit demand. Let me discuss these in order.

In theory, there are a number of variables affecting transit demand which are omitted from the equations in Table 2-3. Most important are various levels of service indicators for transit and competing modes. For example, it is well known that transit demand responds to the amount of time it takes to make a trip, to reliability of service and to the distance which a patron must walk in order to complete the trip. In addition, there are compelling theoretical reasons to believe that the prices and level of service for alternative modes (taxi, private bus and car services, and private auto) would affect public transit demand.

Variables representing these factors were tested in the regression equations with, sometimes, disappointing results. Specifically, prices of competing modes--represented by taxi fares, gasoline cost per gallon, and tunnel and bridge tolls--were not statistically significant.

Alternatively, transit level of service variables were included and produced satisfactory results. For example, bus miles has an elasticity near unity (see Table 2-3). Bus miles represents an aggregate of level of service factors such as frequency, route density, area of coverage and hours of service. All of these affect the convenience and accessibility of transit to users and, correspondingly, should have an impact on demand. The elasticity of unity is higher than the average estimated for other cities but is not outside the range of previous

estimates and is even lower than previous estimates for the NYCTA.[5] The level of service elasticities for subway are much lower reflecting, it can be presumed, the fixed-route character of rapid transit and the lack of alternatives to passengers.

The second issue involves the distinction between short-run and long-run elasticity. In the specification of the demand equations used in this study, the elasticity of demand can be visualized as having three components: first, a short run component which is represented by the coefficient, b_1, on transit fare; second, a long run feedback effect of employment on demand which is the coefficient, b_2, on employment times the elasticity of employment with respect to fare, NE;[6] and, third, the long run adjustment factor which is a function of k, the coefficient on the dependent variable lagged 12 months.

It would be of some interest to test the hypothesis that the long run elasticity of demand is greater than the short run elasticity. One way to test this hypothesis is to determine whether the coefficient k is statistically significant--which it is. Another test would be one where alternative equations for travel demand were formulated--one which constrained the long run elasticity to be equal to the short run elasticity--and then compare these to the equations presented in Table 2-3. However, such a comparison would not be informative in this case because extremely high R-square statistics are being achieved among alternative specifications. Consequently, we must rely on the significance of k, as well as common sense, to accept the proposition that the long run elasticity is greater than the short run elasticity.

The third problem involves the presence of serial correlation in specifications which include the lagged endogenous variable. In the instant case,

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5 See Armando M. Lago, Patrick Mayworm and J. Matthew McEnroe, "Transit Service Elasticities," Journal of Transport Economics and Policy, May 1981, pp. 104-105.

6 NE is estimated in Section III.

first order serial correlation was found and corrected using the iterative Cochran-Orcutt procedure.[7] It is well known that the standard correction for first order auto-correlation is biased (as will be the estimate of k) in equations with a lagged dependent variable.[8] However, in the instant case, we can ignore this problem. The reason for this is that the dependent variable is actually lagged 12 periods rather than one period. Though first order autocorrelation would still create twelfth order autocorrelation, it is less than .0005 in the estimated equations and, consequently, can be ignored. Twelfth order autocorrelation from other sources has been effectively removed by using monthly dummy variables.

The final statistical problem is that employment and transit demand are co-determined in this model. To see this, note that transit fare (lagged twelve months) effects the level of employment in the equations estimated in Section III and, simultaneously, the level of employment effects transit demand in the equations in Table 2-3. Though the presence of a lagged fare variable in the employment equation mitigates this problem, there is still the potential for simultaneous equations bias in the coefficient estimates of the transit demand equations. To solve this problem, instrumental variables were used for the employment variable in the transit demand equation. The instruments are the exogenous variables in the labor market equations in Section III.

Let me now turn to the reasonableness of individual parameter estimates. As can be seen, the estimated coefficients have signs and magnitudes which are appropriate. The short run elasticity of demand for subways is -.238 and for buses is -.288; both are reasonable in the light of estimates found by other researchers reviewed above.

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7 See Johnston, pp. 259-265. This procedure is part of SAS.

8 Id. pp. 307-313.

The coefficients on employment are also of expected magnitudes: they are 1.064 for subway demand and .941 for bus demand. Taking a weighted average (.63 for subway and .37 for bus) produces a system-wide elasticity of 1.018. This means that transit trips increase at almost the same rate as employment growth. Such a result is quite plausible.

The coefficient on the lagged dependent variable has, as mentioned before, the expected sign and is statistically significant. This means that the long run elasticity of demand is greater than the short run elasticity. However, the magnitude of the coefficient is not large in either regression--it is .150 in the subway equation and is .260 in the bus equation. Ignoring employment effects, this means that the long run subway elasticity is 1.176 times its short run elasticity and the long run bus elasticity is 1.351 times its short run elasticity.

The remaining coefficients are mainly on variables which correct for month to month variations or outliers caused by extraordinary events. They have expected signs and magnitudes.

Overall, the test statistics show that the regressions fit the data extremely well. Given this, and the other considerations mentioned above, these equations seem to be quite reasonable.

C. Computation of Long Run Elasticity

Formula (9) is used to compute the long run fare elasticity for subway and bus demand separately. The values of the estimated parameters are as follows:

	Subway	Bus
b_1	-.238	-.288
b_2	1.064	.941
k	.151	.260
NE	-.040	-.040
$NL = \frac{b_1 + b_2 NE}{1-k}$	-.330	-.440

The aggregate, system-wide elasticity is -.371 (=-.330 x .63 -.440 x .37).

It is interesting to separate the long run elasticity into the components mentioned earlier: first, a short run elasticity; second, a long run elasticity which ignores the feedback effects of employment; and, third, a long run elasticity which includes the feedback effects of employment. The following table presents the relevant computations:

	Subway (1)	Bus (2)	System .63 x(1) + .37 x(2)
b_1	-.238	-.288	-.257
$\frac{b_1}{1-k}$	-.280	-.389	-.320
NL	-.330	-.440	-.371

As can be seen, the long run system elasticity is over 40 percent greater than the short run elasticity. The Koyck lag contributes -.063 to the long run elasticity and the employment effects contribute -.051. The next section describes the employment equations which were used to estimate this contribution.

III. ESTIMATES OF THE EFFECT OF TRANSIT FARES ON NEW YORK CITY EMPLOYMENT

This section describes the econometric equations used to isolate the effects of transit fares on New York City employment. Briefly stated, these are of demand and supply functions for labor in New York City. One of the variables in these functions is the level of transit fares. The conceptual basis of these equations is explained in the first part of this section. This is followed by a presentation of the econometric results and a discussion of their reasonableness.

A. The Demand and Supply for Employment in New York City

Transit fares have several long run effects on economic activity in New York City which were highlighted in the Statement, infra. For the purposes of exposition, these effects can be put in terms of their ultimate impacts on either the demand or supply of labor in the City. In review, these impacts are as follows:

1. Employment Demand: As transit fares increase, the amount of personal business in the City will decline. This, in turn, will cause a decline in the demand for employment in these activities (e.g., retail sales, entertainment, etc.).
2. Employment Supply: Employees will require compensating wage increases when their costs of living increase. As transit fares increase, the amount of labor available at any given wage rate will decline--either through out-migration, reduced labor force participation or finding substitute jobs outside of the City.

There are, of course, other factors which influence the demand and/or supply for labor in New York City. The most important of these are as follows:

1. New York City Wage Levels: Clearly one of the most important influences on employment will be wages. As wages increase,

employers will tend to relocate outside of New York City; also, as wage increases force up the price of goods and services produced in New York City, these will become less competitive with goods and services produced elsewhere. On the supply side, higher wages cause an increase in labor supply from increased in-migration (or decreased out-migration), increased labor force participation, and increased switching from jobs outside of the City.

2. National Wage Levels: Wages outside of New York City will have reverse effects. As national wage rates increase (holding New York City wage rates constant) the demand for New York City labor will increase. Alternatively, increases in national wage rates will cause out-migration from the City thereby reducing local labor supply.

3. U.S. Economic Activity: The demand for New York City employment will also be affected by the demand for goods and services exported from the city to the rest of the country. The level of such exports will depend upon, among other things, the economic health--employment and income--of the nation.

4. Nontransit Transportation Costs: Transportation costs affect both the demand and supply for New York City labor though the direction of the effect is uncertain in both cases. On the demand side, transportation costs affect the imports and exports of New York City's goods and services; both will decline if transportation costs increase. However, it is possible for them to decline in different proportion. For example, if imports are

transportation intensive whereas exports are not, then an increase in transportation costs would cause a greater decline in imports than in exports; this would mean that local labor demand would increase to produce the goods and services which substitute for the lost imports. On the supply side, the results are also ambiguous. Transportation costs affect the relative standard of living between NYC and other cities. If an increase in, say, gas prices causes areas outside of the City to be less attractive, then in-migration will cause a larger labor supply. Alternatively, higher gas prices also increase the costs of commuting to the City which, in turn, could cause suburban and exurban workers to exit from the New York City labor market.

5. Other Trends: There are a large number of other factors which affect levels of employment in New York City but which are often difficult to quantify. These include the pattern of federal government expenditures on public works and military projects which, it is generally believed, have been disproportionately outside of the Northeast. Also, prices of other factors of production (e.g., land, capital and natural resources) will cause changes in employment location. Finally, broad demographic trends, including those affected by the quality of life, will influence the composition and size of the labor force as well as the demand for labor; more specifically, (1) migration from Northeastern big cities to exurbs and sunbelt cities reduces local labor supply and (2) the factors causing this migration (e.g., the perceived quality of life in New York relative to other areas)

may cause employers to relocate themselves thereby taking employment opportunities with them.

To take account of all these factors in a sophisticated fashion would be a major research undertaking. Because I have the more limited goal of simply determining the effects of transit fares on employment--rather than developing a complete model of New York City's labor market--some shortcuts are possible. A rather simplified model of the labor market, which can be estimated from readily available data and takes account of transit fares, is as follows:

(1) New York City Employment Demand = a_0 + a_1 (New York City Wage Rates) + a_2 (Transit Fares) + a_3 (U.S. Wage Rates) + a_4 (Other Transportation Costs) + a_5 (U.S. Economic Activity) + a_6 (Time Trend)

(2) New York City Employment Supply = b_0 + b_1 (New York City Wage Rates) + b_2 (Transit Fares) + b_3 (U.S. Wage Rates) + b_4 (Other Transportation Costs) + b_5 (Time Trend)

(3) New York City Employment Demand = New York City Employment Supply

Where the coefficients ($a_0 \ldots a_6$, $b_0 \ldots b_5$) are to be estimated.

To add more realism to the model, certain adjustments to equations (1) and (2) should be made. The first of these is to put all variables except Time into natural logarithms. By doing this, each of the coefficients is interpreted as an elasticity; for example, a_1 measures the percentage change in employment demand caused by a one percent increase in wage rates. The second adjustment is to lag by one year many of the variables on the right-hand side of the above equations. This takes account of the time needed by employers and households to make changes in response to new conditions.

Two other adjustments have been made to simplify the estimation of the coefficients. The first of these is that Gas Price has been used as a proxy variable for Other Transportation Costs. The second is that U.S. Employment has been used as a proxy variable for U.S. Economic Activity.

Using abbreviations for the variables in equations (1) and (2), the final form of the model can be written as follows:

(4) $\ln NYCED = a_0 + a_1 \ln NYCWR + a_2 \ln TF(-1) + a_3 \ln USWR(-1) + a_4 \ln PG(-1) + a_5 \ln USE + a_6 T + u$

(5) $\ln NYCES = b_0 + b_1 \ln NYCWR + b_2 \ln TF(-1) + b_3 \ln USWR(-1) + b_4 \ln PG(-1) + b_5 T + v$

(6) $\ln NYCED = \ln NYCES + w$

where: $a_0 \ldots a_6$, $b_0 \ldots b_5$ are coefficients to be estimated;

ln X means that the natural logarithm of variable X is being used;

(-1) means the value of variable X 12 months earlier (i.e., lagged one year);

u, v and w are stochastic error terms.

Because wage rates are simultaneously determined with observed employment, estimation of the coefficients in equations (4) and (5) is not straightforward. This as well as other statistical issues are discussed in the following section.

B. Equation Estimation

The presence of simultaneously determined variables in equations (4) and (5) does not allow us to use ordinary least squares (OLS) on the equations as formulated. Such a regression would not yield estimates of the coefficients. There are several econometric techniques which can be used to solve this problem. The

approach we have taken is to estimate a reduced form of the model and solve algebraically for the coefficients using extraneous information on their values.[9] First, I will describe the reduced form equations and then the approach taken to recover the structural equations ((4) and (5)).

The reduced form is a set of equations with the simultaneously determined variables (employment and wages) only on the left side of the equations. All exogenous or lagged endogenous (predetermined) variables are on the right side of the equations. For the present, let us ignore the error terms and let NYCE = NYCES = NYCED. Then the equations (4) and (5) can be rewritten as follows:

$$\text{(7) } \ln NYCE = \frac{b_1a_0 - a_1b_0}{b_1 - a_1} + \frac{b_1a2 - a_1b_2}{b_1 - a_1} \ln TF(-1) + \frac{b_1a_3 - a_1b_3}{b_1 - a_1} \ln USWR(-1) + \frac{b_1a_4 - a_1b_4}{b_1 - a_1} \ln PG(-1) + \frac{b_1a_5}{b_1 - a_1} \ln USE + \frac{b_1a_6 - a_1b_5}{b_1 - a_1} T$$

$$\text{(8) } \ln NYCWR = \frac{a_0 - b_0}{b_1 - a_1} + \frac{a_2 - b_2}{b_1 - a_1} \ln TF(-1) + \frac{a_3 - b_3}{b_1 - a_1} \ln USWR(-1) + \frac{a4 - b_4}{b_1 - a_1} \ln PG(-1) + \frac{a_5}{b_1 - a_1} \ln USE + \frac{a_6 - b_5}{b_1 - a_1} T$$

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9 For an introduction to the problem of estimating supply and demand equations simultaneously, see Lawrence R. Klein, An Introduction to Econometrics (Englewood Cliffs, NJ: Prentice-Hall, Inc., 1962), Chapter 2. A more advanced treatment of this problem is given in such econometric texts as Henri Theil, Principles of Econometrics (New York: John Wiley & Sons, Inc., 1971), Chapter 9 and J. Johnston, Econometric Methods, Second Edition, (New York: McGraw-Hill Book Company, 1972), Chapters 12 and 13.

It should be noted that without extra information, the model is underidentified. That is, equations (4) and (5) cannot be recovered from the coefficients which are estimated for equations (7) and (8).

However, an estimate of equation (7) still satisfies the primary purpose of the model. That is, equation (7) isolates the effects of transit fare on employment levels in New York City.

Regression results for equations (7) and (8) are presented in Table 2-5.[10] (The definition of variables and sources of data are presented in Table 2-6.) Initial estimates of these equations, with OLS, showed that autocorrelation was present. Consequently, this was corrected by estimating a first-order autoregressive term which is used in the regression results in Table 2-5.[11]

The coefficient on transit fare (ln TF(-1)) in the employment regression (ln NYCE) is the elasticity of New York City employment with respect to transit fare. As can be seen, it equals -.040. This is the value which is used in computing long run transit elasticities and employment effects in Section II above.

The test statistics of the regressions are also presented in Table 2-5. However, because these are reduced-form equations they are not as informative about the model as would be test statistics on structural equations. In particular, the low t-statistics on some coefficients are not meaningful because this may be caused by a coefficient whose value is close to zero; the value of such a coefficient still must be used in computing the parameters of the structural equation. Alternatively, high R-squares for reduced form equations would be indicative of a structural model which would fit the data well. The R-square for employment

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10 The software used for estimating these regressions was also SAS.

11 Given that the data are monthly, it was also natural to suspect that twelfth order autocorrelation was present. This hypothesis was tested and could not be accepted. Consequently, no adjustment for potential twelfth order autocorrelation has been made.

(.963) is very high but the R-square wage rates (.577) is less than usual for time series analysis even allowing for the fact that one usually achieves lower R-squares on monthly data as opposed to annual data. Thus, analysis of the test-statistics is ambiguous.

Probably the best way to evaluate these equations is to determine whether the implied structural model is reasonable. This subject is discussed next.

C. Analysis of Structural Equations

The values of the structural parameters give one an intuitive test of the reasonableness of the model. Unfortunately, most of the structural parameters ($a_0 \ldots a_6$, $b_0 \ldots b_5$) in equations (4) and (5) cannot be determined solely from the coefficients estimated in regression equations (7) and (8). As mentioned before, without extra information on individual parameters in equations (1) and (2), the model is underidentified.

Fortunately, there is a solution to this problem. It involves the following steps:

1. First, we note that one of the parameters--b_1, the elasticity of labor supply with respect to New York City wage levels--can be identified from the reduced form equations. Specifically, it is equal to the ratio of the coefficient on ln USE in the ln NYCE regression to the coefficient on ln USE in the ln NYWR regression.

2. Second, the elasticity of employment demand with respect to transit fare (a_2 in equation (4)) is knowable within a certain range. At the upper bound, this would equal zero--i.e., no effect. At the lower bound, the change in employment demand would be solely as a consequence of reduced non-work trips.

Table 2-7 uses exogenous information to derive this lower bound elasticity which is equal to -.008.

3. Using either of the two values for a_2 derived in the previous step (0 and -.008), one can then solve for a_1 and b_2 using the coefficients of ln TF(-1) in equations (7) and (8).

4. Using either of the two values for a_1 derived in the previous step, and the value for b1 derived in the first step, one can solve for the remaining parameters (a_0, a_3, a_4, a_5, a_6, b_0, b_3, b_4, b_5) using the coefficients in (7) and (8).[12]

These steps were performed for the two values of a_2 which bound the employment demand elasticity with respect to transit fare. The results are as follows:

Structural Equations with $a_2 = 0$

(4') ln NYCED = -1.762 - 1.215 ln NYCWR -.022 ln USWR(-1)
+ .080 ln PG(-1) + 1.218 ln USE -.004T

(5') ln NYCES = -16.170 + 3.232 ln NYCWR -.146 ln TF(-1)
- .118 ln USWR(-1) + .182 ln PG(-1) -.0005T

Structural Equations with $a_2 = -.008$

(4") ln NYCED = -2.552 - .971 ln NYCWR -.008 ln TF(-1)
- .027 ln USWR(-1) + .086 ln PG(-1)
+ 1.151 ln USE -.004T

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12 One complication should be noted. The constant terms presented in Table 2-5 must be divided by (1.0-rho), where rho is the correction for first order autocorrelation, before solving for the structural parameters. This was done in the calculations which follow.

$$(5'')\ \ln NYCES = -16.173 + 3.233 \ln NYCWR - .146 \ln TF(-1) - .118 \ln USWR(-1) + .182 \ln PG(-1) - .0005T$$

In evaluating these models, first note that the value of a_2 has very little impact on the value of the rest of the parameters. For all practical purposes, the two models are equivalent.

The signs and general magnitudes of all parameters are reasonable with one exception--the elasticity of New York employment demand with respect to U.S. wage rates, should be positive rather than negative. However, the value of this parameter is small reflecting, to large extent, a high standard error on the coefficient of ln USWR(-1) in the reduced form wage rate equation.

Other features of the model include a high elasticity of both supply and demand with respect to wage rates. Also, the elasticity of New York City's employment demand with respect to U.S. employment is near unity. Both supply and demand have downward secular trends. Demand declines about 4.9 percent annually whereas supply declines at a modest 0.6 percent annually (note that the coefficients on time are for monthly observations and must be compounded to get annual trends). As expected, increases in U.S. wage rates cause reductions in New York City labor supply.

The elasticities of supply and demand with respect to transportation prices also have reasonable interpretations. Increases in the price of gasoline cause both higher demand and supply; this suggests that the city's comparative advantage improves as national transportation costs increase.

A more specific test of the reasonableness of the parameters on transit is to determine the effect of a transit fare increase on wage rates. The coefficient on ln TF(-1) in equation (7) (New York City Wage Rates) is .033 (see

Table 2-5). This implies that a doubling of transit fares causes a 3.3 percent increase in wages. Consider that on average there are 9.4 public transit trips per week for each New York City employee and, for the last month in the sample (February 1982), the average weekly wage of these employees was $256.[13] A doubling of the current transit fare would result in an increase of expenditures which are 2.8 percent of current wages (=(9.4 x .75)/256). Allowing for tax effects--workers have to be compensated more in pre-tax income than the amount of the expenditure just to stay even--it would seem that the 3.3 percent wage impact is a reasonable estimate.

For the most part, the structural equations appear to be plausible and gives us confidence in our use of the elasticity of employment with respect to transit fare which is estimated in the reduced form employment equation.

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13 New York City public transit authorities carried 30.9 million passengers per week in 1980 (Tri-State, Annual Transportation Report, June 1982, p. 23). New York City employment was 3.3 million in 1980 (U.S. Department of Labor, Bureau of Labor Statistics, Employment and Earnings, May 1982, pp. 112-113). Trips per employee then equals 30.9/3.3. The wage data are from the source cited in Table 2-6.

TABLE 2-1

SHORT RUN TRANSIT FARE ELASTICITY ESTIMATES FROM STUDIES OF NEW YORK CITY FARE CHANGES

	Subway Fare Elasticity (1)	Bus Fare Elasticity (2)
(1) Finch (1981)	-.1322	-.3355
(2) Khisty, Kaftanski (1981)	-.2035	-
(3) RPA (1977)	-.117 to -.125	-
(4) Obinani (1977)	-.14	-.32
(5) Lassow (1966)	-.08 to -.21	-.36
(6) Pucher, Rothenberg (Review, 1976)	-.08 to -.25	-.16 to -.59
(7) Hart (1980)	-.23	-.33

Sources:

Row (1): Jerry Finch, "Transit Ridership and Revenue Projections," The City of New York, The President of the Council, May 27, 1981, Tables B-1, B-2, B-3, B-5 and B-6 and The Transit Record, New York City Transit Authority.

Row (2): C. J. Khisty and P. J. Kaftanski, "Demand Analysis of New York Subway System," Transportation Research Record, No. 797 (1981), p. 23.

Row (3): Regional Plan Association, "Power for the MTA," RPA Bulletin 126, June 1977, p. 37.

Row (4): Felix C. Obinani, "Analysis of User Response to the 1975 New York City Transit-Fare Increase," Transportation Research Record, No. 625 (1977), p. 13.

Row (5): William Lassow, "Effect of the Fare Increase of July 1966 on the Number of Passengers Carried on the New York City Transit System," Transportation Research Record, No. 213 (1968), pp. 2, 4 and 5.

Row (6): John R. Pucher and Jerome Rothenberg, "Pricing in Urban Transportation: A Survey of Empirical Evidence on the Elasticity of Travel Demand," for U.S. Department of Transportation Grant No. DOT-OS- 50240, p. 63.

Row (7): Fred C. Hart Associates, Inc., "Final Environmental Impact Statement: Metropolitan Transit Authority's Proposed Fare Actions," June 1980, pp. 43 and 45.

TABLE 2-2

ESTIMATES OF TRANSIT FARE ELASTICITIES FROM VARIOUS MODELS OF TRAVEL BEHAVIOR

	Transit Trips					
	All Trip Purposes Combined		Work Trips			Shopping Trips
	Subway (1)	Bus (2)	Subway/Rail (3)	Bus (4)	Subway/Rail/Bus Combined (5)	Subway/Rail/Bus Combined (6)
(1) Domenciech-Kraft Boston Model (1970)	-	-	-	-	-.09	-.323
Pucher & Rothenberg Review (1976):						
(2) Talvitie Chicago Model	-	-	-.51	-1.8	-	-
(3) McFadden San Francisco Transit Corridor Model	-	-	-.86	-.58	-	-
(4) Other Models of Non-captive Transit Riders	-	-	-	-	-.19 to -.96	-
(5) Chan & Ou Review of Elasticities from Demand Models for Large Cities	-.86 to -1.86	-0.1 to -0.58	-	-	-	-

Sources

Row (1): Thomas A. Domenciech and Gerald Kraft, Free Transit (Cambridge, MA: Charles River Associates, 1970), p. 18.

Row (2): John R. Pucher and Jerome Rothenberg, "Pricing in Urban Transportation: A Survey of Empirical Evidence on the Elasticity of Travel Demand," for U.S. Department of Transportation, Grant No. DOT-OS-50240, p. 36.

Row (3): Id., p. 51.

Row (4): Id., p. 61.

Row (5): Y. Chan and F. L. Ou "Tabulating Demand Elasticities for Urban Travel Forecasting," in Transportation Research Record 673, 1978, p. 44.

COEFFICIENT ESTIMATES AND TEST STATISTICS FOR SUBWAY AND BUS DEMAND EQUATIONS

Independent Variable [1]	Dependent Variable: ln SR Coefficient (1)	ln SR t-Statistic (2)	ln BR Coefficient (3)	ln BR t-Statistic (4)
Constant	-6.758	-4.78	-8.127	-3.13
ln TF [2]	-0.238	-6.29 [5]	-0.288	-5.21 [5]
ln E [3]	1.064	5.79	0.941	2.78
ln SR (-12) [4]	0.151	3.23	N/A	N/A
ln BR (-12) [4]	N/A	N/A	0.260	3.68
ln WD	0.498	16.08	0.286	4.44
ln TM [2]	0.004	1.49 [5]	N/A	N/A
ln MDBF [2]	0.029	2.71 [5]	N/A	N/A
ln BM [2]	N/A	N/A	0.976	5.00
SUH	-0.014	-1.34	0.052	2.16
SAH	0.054	5.59	0.025	1.33
STK	-0.512	-25.53	-0.403	-8.71
STK (-12)	0.063	2.16	0.139	3.24
BLO	-0.048	-2.93	0.015	0.49
STM	0.016	1.02	-0.032	-1.10
JAN	-0.010	-1.57	-0.011	-0.92
FEB	-0.015	-1.58	0.012	0.66
MAR	0.002	0.29	0.028	1.55
APR	-0.017	-2.08	0.011	0.65
MAY	-0.002	-0.29	0.064	3.57
JUN	-0.004	-0.51	0.038	2.35
JUL	-0.089	-9.19	-0.111	-6.06
AUG	-0.112	-11.23	-0.147	-7.62
SEP	-0.053	-5.85	0.003	0.22
OCT	0.007	0.92	0.043	2.87
NOV	0.022	2.83	0.026	1.71

Test Statistics	Dependent Variable ln SR	ln BR
Adjusted R-Squared	.966	.960
F-Statistic	166.78	108.82
Correction for First Order Autocorrelation	.384	.400
Degrees of Freedom	105	77
Period of Analysis	Jan. 1971 to Feb. 1982	July 1973 to Feb. 1982

NA - Not applicable.

[1] Variable definitions and data sources are listed in Table 2-2.

[2] Estimated as an Almon first degree polynomial lag over four months. The monthly coefficients for subway fare are -.079TF - .066TF(-1) - .053TF(-2) -.040TF(-3). The monthly coefficients for bus fare are -.258TF - .134TF(-1) - .010TF(-2) + .114TF(-3). The monthly coefficients for train miles are .040TM + .014TM(-1) - .012TM(-2) - .038TM(-3). The monthly coefficients for mean distance between failures are .006MDBF + .007MDBF(-1) + .008MDBF(-2) + .008MDBF(-3). The monthly coefficients for bus miles are .289BM + .259BM(-1) + .229BM(-2) + .199BM(-3).

[3] The employment variable is treated as jointly dependent. It is replaced by its predicted value from instrumental variables; these are the exogenous variables of the employment equation in Section III (see Table 2-5).

[4] A lag of (-12) denotes the value of the variable in the same month of the prior year (i.e. a lag of 12 months).

[5] The t-statistic for the sum of the coefficients, b_i, on a set of lagged variables, X(-i), is obtained from the statistic on the coefficient of the variable, $\frac{\Sigma b_i X(-i)}{\Sigma b_i}$ in a separate regression which is otherwise identical.

DEFINITION OF VARIABLES AND SOURCES OF DATA FOR TRAVEL DEMAND EQUATIONS

Variables	Definitions and Sources
SR	= Monthly NYCTA subway revenue passengers (in millions).
	SOURCE: New York City Transit Authority, The Transit Record, monthly editions. Metropolitan Transportation Authority, "Performance Progress Report," March 1982.
BR	= Monthly bus revenue passengers (in millions) on NYCTA and MaBSTOA bus lines.
	SOURCE: New York City Transit Authority, The Transit Record, monthly editions. Manhattan and the Bronx Surface Transit Operating Authority, Budget Department. Metropolitan Transportation Authority, "Performance Progress Report," March 1982.
TF	= Average deflated New York City subway/bus fare (in dollars).
	SOURCE: Metropolitan Transportation Authority. New York City Consumer Price Index.
E	= Total monthly employees (in thousands) on non-agricultural payrolls in New York City.
	SOURCE: New York State Department of Labor, Employees on Non-agricultural Payrolls by Industry, 1958-1982.
WD	= Work days per month.
	SOURCE: Information Please Almanac 1982. New York: Simon and Schuster, 1981.

Variables	Definitions and Sources
BM	= Monthly revenue vehicle bus miles traveled by NYCTA and MaBSTOA surface vehicles (in miles). SOURCE: New York City Transit Authority, The Transit Record, monthly editions. Manhattan and the Bronx Surface Transit Operating Authority, Budget Department. Metropolitan Transportation Authority, "Performance Progress Report," March 1982.
TM	= Revenue car miles; sum of in-service miles operated by each subway car per month. SOURCE: Metropolitan Transportation Authority, "Quarterly Performance Progress Report," March 1982 and New York City Transit Authority.
MDBF	= Fleet Mean Distance Between Failures; the average number of miles a subway car is operated before it experiences a mechanical failure while in revenue service. SOURCE: Metropolitan Transportation Authority, "Quarterly Performance Progress Report," March 1982 and New York City Transit Authority.
T	= Time in months; set equal to 1 in January 1970 and increasing to 146 in February 1982.

Dummy Variables	Purpose and Dates
SUH	= 1 For MTA Sunday Half-fare Policy (December 1973-April 1980) 0 Otherwise
SAH	= 1 For MTA Saturday Half-fare Policy (September 1975-April 1980) 0 Otherwise

Dummy Variables		Purpose and Dates
STK	= 1	For MTA Labor Strike (April 1980)
	0	Otherwise
BLO	= 1	For New York City Electric Balckout (July 1977)
	0	Otherwise
STM	= 1	For Northeast Blizzard (February 1978)
	0	Otherwise
JAN	= 1	In January
	0	Otherwise
FEB	= 1	In February
	0	Otherwise
MAR	= 1	In March
	0	Otherwise
APR	= 1	In April
	0	Otherwise
MAY	= 1	In May
	0	Otherwise
JUN	= 1	In June
	0	Otherwise
JUL	= 1	In July
	0	Otherwise
AUG	= 1	In August
	0	Otherwise
SEP	= 1	In September
	0	Otherwise
OCT	= 1	In October
	0	Otherwise
NOV	= 1	In November
	0	Otherwise

COEFFICIENT ESTIMATES AND TEST STATISTICS FOR REDUCED FORM EMPLOYMENT SUPPLY AND DEMAND EQUATIONS

Independent Variables[1,2]	Coefficients (and t-Statistics) for Equations with the Following Dependent Variable	
	ln NYCE[3] (1)	ln NYWR[3] (2)
Constant Term	-1.413 (-1.45)	1.458 (1.03)
ln TF(-1)	-.040 (-1.97)	.033 (1.15)
ln USWF	-.048 (1.98)	.022 (.50)
ln PG (-1)	.108 (5.04)	-.023 (-.85)
ln USE	.885 (9.99)	.274 (2.13)
T	-.003 (-12.87)	-.0007 (-2.33)
Test Statistics		
R- Squared Corrected	.963	.577
F- Statistic	684.10	37.41
Correction for First Order Autocorrelation	.752	.550
Degress of Freedom	127	127
Period of Analysis	Jan. 1971 to Feb. 1982	Jan. 1971 to Feb. 1982

[1]Definition and sources are in Table 4-1.
[2]Data are monthly observations. A lag of (-1) is the previous year's value (i.e., a lag of 12 months).
[3]Values in parentheses are t- Statistics.

TABLE 2-6

DEFINITION OF VARIABLES AND SOURCES OF DATA FOR EMPLOYMENT SUPPLY AND DEMAND FQUATIONS

Variables	Definitions and Sources
NYCE	Total monthly employees in thousands on non-agricultural payrolls in New York City;
	New York State Department of Labor, Employees on Non-agricultural Payrolls by Industry, 1958-1982.
NYWR	Average weekly wage weighted by industry employment, and deflated by New York Consumer Price Index, based on wages from the following industries: manufacturing, retail trade, banking (as a sub-industry of finance, insurance and real estate) and hotels (as a sub-industry of services);
	Employment Review, monthly editions, New York State Department of Labor, Division of Research and Statistics.
USE	Total number of employees in non-agricultural establishments;
	Employment and Earnings, monthly editions and annual supplements, United States Department of Labor, Bureau of Labor Statistics.
USWR	Average weekly non-supervisory wage weighted by New York City employment, and deflated by U.S. City Consumer Price Index, based on the following industries: manufacturing, retail trade, finance, insurance and real estate, and services;
	Employment and Earnings, monthly editions and annual supplements, United States Department of Labor, Bureau of Labor Statistics.
TF	Average deflated monthly New York City subway/bus fare;
	Metropolitan Transportation Authority.
PG	Average deflated monthly retail price of a gallon of regular leaded gasoline in the New York area;
	Platt's Oil Price Handbook and Oilmanac (New York: McGraw-Hill, Inc., 1970-1981. "The Lundberg Letter," Lundberg Survey, Inc., North Hollywood, CA, October 1981-February 1982.

DERIVATION OF LOWER BOUND CONSTRAINT ON COEFFICIENT ON TRANSIT FARE IN THE EMPLOYMENT DEMAND EQUATION

(1)	Nonwork Transit Trip Elasticity	-.421
(2)	Reduced Nonwork Trips as Share of Reduced Transit Nonwork Trips in Response to a Fare Increase	.340
(3)	Share of Nonwork Trips Made by Transit	.490
(4)	Decrease in Number of Stops for Each Trip not Made	.444
(5)	Proportion of Nonwork Trips which Involve Business Activity	.538
(6)	Proportion of New York City Employment Served by Nonwork Trips	.449
(7)	Percent Change in New York City Employment Caused by one Percent Increase in Transit Fare (1)x(2)x(3)x(4)x(5)x(6)	-.008

SOURCES AND NOTES

[1] Computed by noting the following relationships:

short run system elasticity =

(work trip share x work trip elasticity + nonwork trip share x nonwork elasticity)

and

2.5 x work trip elasticity = nonwork trip elasticity

from infra we know that:

short run system elasticity = -.257

work trip share = .65

nonwork trip share = .35

from which we can solve for the nonwork trip elasticity.

[2] Both Tri-State ITR 5303, p. B-9 and Obinani (p. 13) find that 50 percent of reduced nonwork trips are diverted to another mode, assumed to be auto-based, in response to a fare increase. An unknown number of other trips are diverted to walking. However, for the work trip, 16 percent of those who reduced transit travel switched to walking (Oinani, p. 12). Assuming similar behavior for nonwork trips yields 66 percent of trips diverted to other means and 34 percent fewer trips in total.

[3] Kornhauser, p. 132.

[4] Derived from the elasticity of trip distance with respect to number of trips (= -.556) in a nonwork travel model in Charles River Associates. Estimating the Effects of Urban Travel Policies (Boston, MA: 1976) pp. 135, 142. The number of stops is assumed to be proportional to distance. Thus, stops reduced is equal to 1.0-.556.

[5] Computed from a survey of Pittsburgh travelers reported in Thomas A. Domencich and Daniel McFadden, Urban Travel Demand (Amsterdam: North-Holland Publishing Co., 1975) Table A-3, p. 188. Single purpose nonwork trips were combined into the following categories: Those which involve business activity include Shop, Personal Business, and Recreation; those which do not involue business activity include School, Social and Riding.

[6] Based on 1977 employment by industry reported in Boris Pushkcarev. "The Future of Manhattan" in New York City's Changing Economic Base Benjamin J. Klebaner, ed. (New York: Pica Press 1981), p. 177. Industries assumed to be serving local residents in whole include Wholesale Trade, Medical and other Health, Real Estate, Restaurants, Legal Services, General Merchandise, Educational Services, Insurance Agents, Apparel Stores, Misc. Retail Store, Motion Pictures, Amusement Services, Household Services, Personal Services. In addition, half of employment from the following categories was assumed to serve local residents: Apparel, Banking, Misc. Services, Misc. Manufacturing. Special Trade Contractors, other 27 Industries. All remaining industries were assigned zero weight.

UNITED STATES OF AMERICA
NUCLEAR REGULATORY COMMISSION

BEFORE THE ATOMIC SAFETY AND LICENSING BOARD

In the Matter of	)	
	)	
CONSOLIDATED EDISON COMPANY OF NEW YORK, INC. (Indian Point, Unit No. 2)	)))	Docket Nos. 50-247 SP 50-286 SP
POWER AUTHORITY OF THE STATE OF NEW YORK (Indian Point, Unit No. 3)	))	April 12, 1983

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I hereby certify that I have served copies of: THE TESTIMONY OF FREDERICK C. DUNBAR UNDER COMMISSION QUESTION 6 to the service list below on this 12th day of April, 1983 by depositing it in the United States mail, first class.

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BEFORE THE ATOMIC SAFETY AND LICENSING BOARD

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In the Matter of	)	
	)	
CONSOLIDATED EDISON COMPANY OF NEW YORK, INC.	)	Docket Nos.
(Indian Point, Unit No. 2)	)	50-247 SP
	)	50-286 SP
POWER AUTHORITY OF THE STATE OF NEW YORK	)	
(Indian Point, Unit No. 3)	)	April 12, 1983

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