

# Commuter Rail Ridership: The Long and the Short Haul

*Richard Voith\**

## INTRODUCTION

Many American cities have commuter rail systems which, in addition to serving their riders, are intended to benefit the region as a whole by reducing congestion and air pollution, enhancing economic development, and providing transportation services to the poor. The degree to which these potential benefits are realized depends upon the number of riders the system can attract. A commuter rail system with little

patronage cannot contribute much to congestion relief or air pollution abatement.

Demand for commuter rail transportation, like the demand for any service, depends upon its price, the price of alternatives, and the quality of the service. Unlike most other services, however, prices or fares in the regional public transportation industry are determined not in the marketplace but by a public authority. Most public transportation systems, including commuter rail systems, depend on state and local governments for subsidies, as fares cover only a portion of the operating cost. Fares, the quality of service, and ultimately the level of ridership,

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\*Richard Voith is an Economist in the Urban and Regional Section of the Research Department of the Federal Reserve Bank of Philadelphia.

will depend on the level of subsidy available for public transportation and on how that subsidy is allocated throughout the service area. When state and local governments decide how much subsidy to provide, they walk a fine line between allocating enough funds to reap the benefits of public transportation and keeping enough budgetary pressure on the transit authority to provide the service in a cost-effective manner.

If lower subsidies induce the transit authority to produce transportation services more efficiently, that is clearly beneficial. Transit authorities, however, often respond to budgetary shortfalls by increasing fares, reducing service, or both. While such actions balance the budget in the current year, they can lead to problems in the future. In the short run, increases in price and reductions in service have a relatively small impact on ridership. But, in the long run, consumers can exercise more options among their commuting alternatives; therefore, ridership may decline after the initial impact of the price increase or service reduction, leaving the system with lower and lower farebox revenues. The difference in commuters' short-run and long-run responses to changes in price and service levels may help explain the familiar cycle of service reductions, increasing fares, and falling ridership often observed in the public transportation industry.

#### **THE EVOLUTION OF COMMUTER RAIL DEMAND**

Consumers are the ultimate judges of public transportation policies, and they evaluate public transportation relative to the price and quality of other alternatives. Important elements in the quality of commuter rail transportation are frequency of service, speed, reliability, and factors affecting comfort, such as crowding and cleanliness. Changes in the price or characteristics of the rail system (or of competing means of transportation) will affect the choices of some consumers immediately, while others will be affected only after some lag as they make long-term decisions.

In the short run, a consumer faces a fairly

narrow set of alternative types of transportation and will choose the most attractive among them to get from place to place. For example, he can choose to drive if he owns a car, or take the train or a bus from home to his place of work. In the short run, the consumer's transportation alternatives themselves and the origins and destinations of trips cannot readily be changed.

Over the longer term, however, a consumer can change his transportation alternatives by making investments, such as purchasing a car or perhaps a second car. He might be able to join a car or van pool to reduce the cost of private transportation. He can even change the origin and destination of his commuting trips by moving or changing employment. Transportation is often a major consideration in such a change. Thus, in the long run a consumer has considerably more options in responding to changes in the relative prices and qualities of various transportation alternatives.

It is not just current price and quality that affect these long-run decisions but future considerations as well. If there is a great deal of uncertainty about the price or the existence of the commuter rail service in the future, the potential benefits of that system are discounted in the consumer's long-term decision.

Taken together, the short-run and long-run decisions of consumers in the entire region determine the evolution of ridership over time. If the price and quality of train service make it an attractive alternative, people and firms are likely to make long-term location and investment decisions that will lead to high levels of ridership in the future. Areas well served by the system will grow and develop. Individuals who work along the train lines will sort themselves into residential locations that have train service. For instance, most systems have a hub in the center of the city so that people who work there will be more likely to live in areas with train service, which will probably raise property values there. On the other hand, people who work where train service is not available will choose to live in areas that are not near train stations to avoid paying

higher housing prices. Locations well served by the train, therefore, will have a disproportionately large number of people who routinely travel by train. Hence, ridership will be high.

On the other hand, if the quality of service is poor, or too expensive, or if future subsidies are uncertain, individuals and firms will not weigh the possibility of future train service heavily in their investment and location decisions. People will invest more in automobiles, making it less likely that they would choose to ride the train in the near future, even if the price and quality of the train service were improved. People may choose to live in areas not served by the train even if their job location has train service. Employers may choose locations not served by the train. As a result, where people live and work would not be consistent with high future ridership.

#### **Setting the Public Transportation Budget.**

Since the transit authority and state and local governments together choose the prices and service levels, they influence the evolution of demand. The transit authority actually sets the fares and service levels within the framework of a balanced budget. Its operating expenses cannot exceed its revenues, which include both proceeds from the farebox and government subsidies. But the authority can only go so far in balancing the budget by cutting operating expenses or increasing fares. Operating expenses cannot be reduced if they result in service levels that are inadequate to sustain consumer demand. And the amount of revenue available from the farebox is limited because riders can opt for other means of transportation if fares are too high.

The other source of revenue for balancing the budget, namely the amount of subsidy available, is a matter of public policy. When state and local governments choose the level of subsidy for public transportation, they weigh a myriad of economic and political considerations.<sup>1</sup> In addi-

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<sup>1</sup>For a discussion of the role of public investment and productivity, see Gerald A. Carlino, "Productivity in Cities: Does City Size Matter?" this issue of the *Business Review*.

tion, they often use legislative review of the subsidy and budgetary restraint to induce the transit authority to minimize waste.<sup>2</sup> The share of expenditures covered by the farebox, or operating ratio, is a common measure of the performance of public transportation authorities. Achieving a high operating ratio, however, may not necessarily coincide with achieving the lowest subsidy cost per passenger. It is possible, for example, for a transit authority to attain a very large share of revenue from the farebox by charging high fares, while having relatively low ridership. In this case the subsidy would benefit few riders, and the benefits in terms of traffic congestion relief would be small. Forcing high fares through low subsidies may result in high subsidy costs on a per rider basis. Since the public benefits of the system depend on the level of ridership, a better goal for policymakers may be to choose the subsidy that minimizes subsidy cost per rider.

#### **The "Catch-22" of Public Transportation.**

There is a trade-off between the reduced waste induced by budgetary restraint and the adverse long-run impacts of higher prices and lower service which may result from a low level of subsidy. In the short run, ridership may not change much in response to changes in price and service levels. Thus, service cuts and fare increases may balance the budget in the current period. But, because of the effect of fares and service levels on people's long-run decisions, the loss in ridership and corresponding decline in farebox revenue resulting from changes in prices and service may be much greater in the long run. In economic terminology, demand is more elastic in the long run than in the short run. (See *SHORT-RUN AND LONG-RUN ELASTICITIES*, p. 16.)

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<sup>2</sup>Several studies have noted a correlation between higher levels of government transit subsidies and higher transit worker wages and lower productivity. See J. Gomez-Ibanez, "The Federal Role in Urban Transportation," in *American Domestic Priorities: An Economic Appraisal*, John M. Quigley and Daniel L. Rubinfeld, eds. (Berkeley: University of California Press, 1985) pp. 183-223.

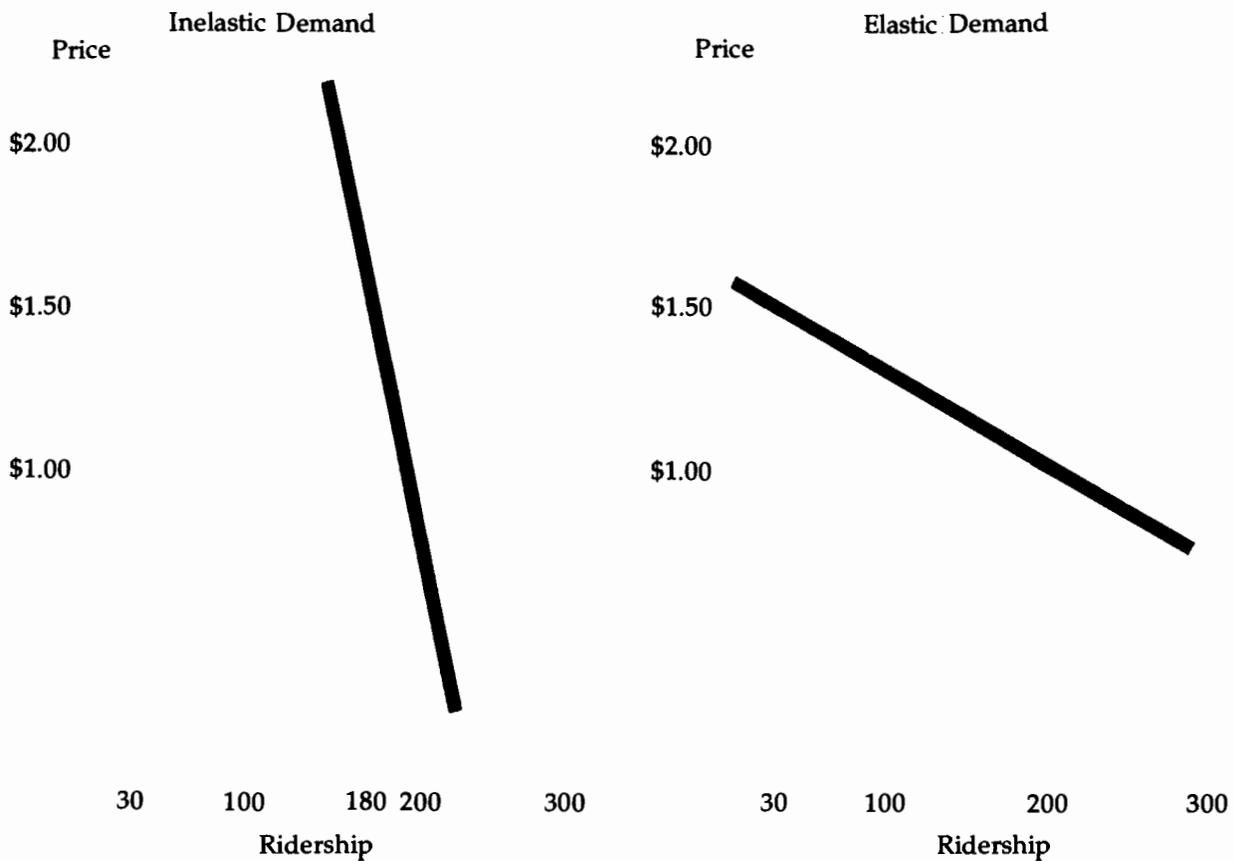
Economists often express the change in demand for a product in response to a change in its price or some other factor in terms of “elasticities”—the percentage change in one thing divided by the percentage change in another. Consider, for example, the price elasticity of train ridership:

$$\text{Elasticity} = \frac{\text{Percent Change in Ridership}}{\text{Percent Change in Price}}$$

If this ratio is more than 1 (ridership, in percentage terms, changes more than price in percentage terms), then price demand is “elastic.” If the ratio is less than 1 (ridership, in percentage terms, changes less than price in percentage terms), then price demand is said to be “inelastic.”

It is a general economic proposition that demand is more elastic in the long run than in the short run. Thus, in some cases, price increases may produce more revenue in the short run, but in the long run during which people have more time to exercise other options, price increases may lead to declines in total revenue.

The graphs below compare examples of elastic and inelastic demand curves to illustrate their effects on total revenues. In both cases, when the railway fare is, say, \$1.00 per ticket, the quantity demanded is 200, and total revenue is \$200. But, if the fare goes up to, say, \$1.50 per ticket, the effect on total revenue is very different depending on the elasticity of demand. Where demand is inelastic, total revenues increase from \$200 to \$270 even though ridership declines somewhat, from 200 to 180. But where demand is elastic, ridership falls so much—from 200 to 30—that revenues are only a small fraction of what they originally were, falling from \$200 to \$45.



If long-run demand is significantly more elastic than short-run demand, then price hikes and service cuts are likely to result in higher long-term subsidy costs per passenger. Because high fares or poor quality service lead people to look for alternatives to the train, revenue from the farebox falls but the large fixed costs of the rail system remain unchanged; thus the governments' cost per rider increases. Since transportation policies are an important factor shaping the development of a region, the long-run and short-run effects of changes in fares and quality of service should be important considerations of both the transit authority and its state and local subsidizers. A prerequisite for formulating rational transportation policy is knowledge of the short-run and long-run impacts of price and service changes.

#### **ANALYZING THE DEMAND FOR COMMUTER RAIL TRANSPORTATION**

From a planning perspective, transit authorities need to know how much the demand for rail transportation is affected by changes in price, quantity, and quality of service. Measuring the total effects of these changes is difficult because the level of ridership depends not only on the price and attributes of train service but also on a number of other factors, such as the number of potential customers, their transportation preferences, their investments in private transportation, and the price and quality of alternatives to the train, such as buses and van pools. The size and makeup of the potential pool of riders play important roles in the level of ridership at any particular location.

Most studies have focused only on the short-run impacts of price and service characteristics on demand, assuming that the choices commuters have now are the only ones available. By observing the choices of many individuals, each facing different circumstances in terms of the prices and attributes of the alternative modes of transportation, the short-run impact of changes in prices and service on their transportation

choices can be measured.<sup>3</sup>

Since these short-run analyses do not take into account the transportation system's impact on individuals' long-term choices, and hence its impact on the potential pool of riders, they underestimate the total impacts of price and service changes. To predict the total impact of changes in the price and service levels of the train system on ridership, one must take into account the effects which may not occur instantaneously, but rather gradually as such changes affect the locational distribution of the regional population and the investment decisions of that population.<sup>4</sup>

By examining the evolution of ridership at particular locations in a region over a period of several years, one can estimate both the long-run and short-run impacts of price and service changes.<sup>5</sup> Fortunately, data are available for this type of analysis from the Southeastern Pennsylvania Transportation Authority (SEPTA) rail system in the Philadelphia area (see the Appendix, pp. 22-23, for technical details of the study). From 1978 to 1986 changes in ridership, prices, and service have varied considerably from station to station in the SEPTA system (see *TRENDS IN SEPTA COMMUTER RAIL RIDERSHIP*, pp. 18-19).

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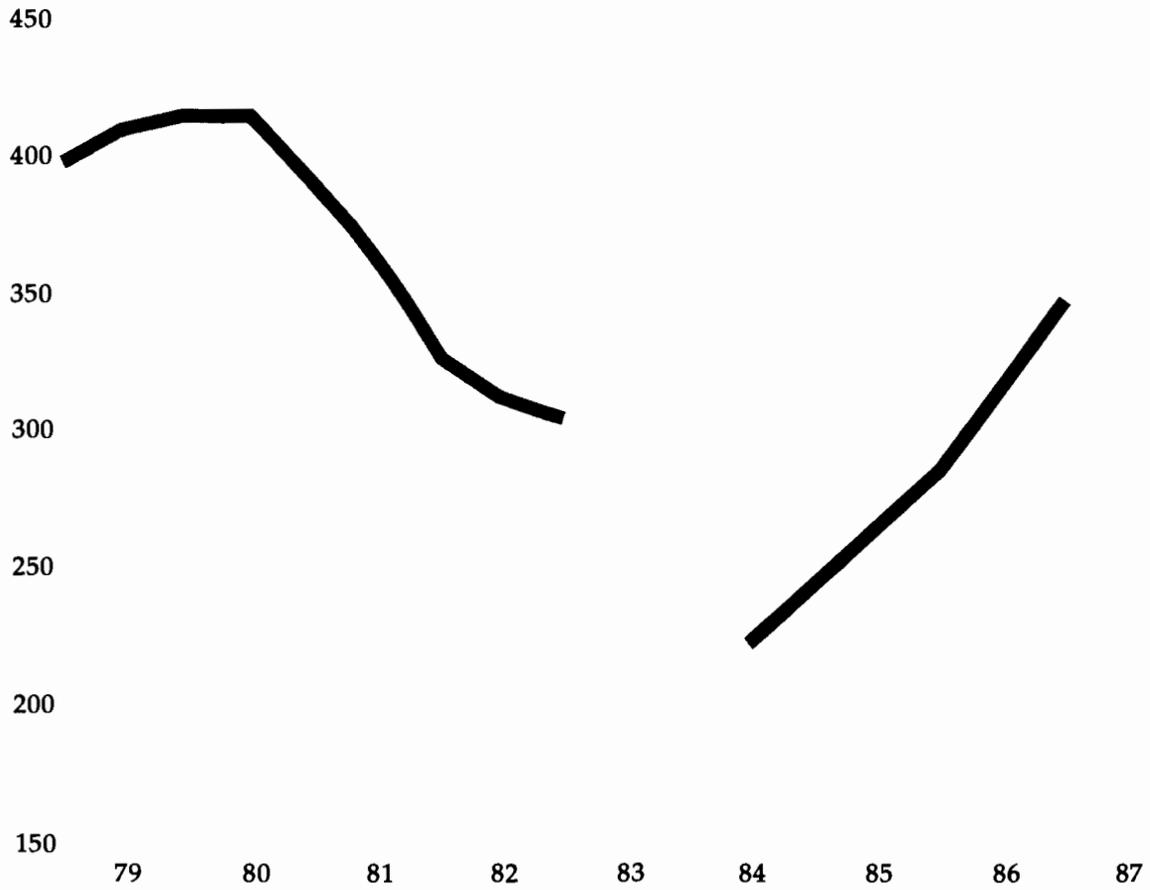
<sup>3</sup>The theory and methods of empirical analysis of individual choice of travel mode in the short run are based on the pioneering work of Daniel McFadden, "Conditional Logit Analysis of Quantal Choice Behavior," in *Frontiers of Econometrics*, Paul Zarembka, ed. (NY: Academic Press, 1974) pp. 105-142.

<sup>4</sup>Mateen Thobani, "A Nested Logit Model of Travel Mode to Work and Auto Ownership," *Journal of Urban Economics*, 15 (1984) pp. 287-301, analyzes the joint decision of purchasing a car and choice of travel mode as functions of the price and attributes of the public transit system. Alex Anas, "Estimation of Multinomial Logit Models of Joint Location and Travel Modal Choice from Aggregated Data," *Journal of Regional Science*, 21 (1981) pp. 223-242, examines the transit system's impact on residential location.

<sup>5</sup>A complete discussion of this methodology is discussed in Richard Voith, "Determinants of Commuter Rail Ridership: The Long and Short Haul," Federal Reserve Bank of Philadelphia Working Paper (forthcoming). A more complete discussion of the data is contained there as well.

### The Overall Trend

Ridership Per Station Per Day  
500



From 1978 to 1980, ridership rose slightly to its peak, but in the next two years declined rapidly as fares increased and service levels fell. In 1983, SEPTA took over operation of the system from Conrail and, in an effort to reduce costs, endured a strike that lasted over three months. The gap in the data is a result of the strike; fall 1982 was the last pre-strike observation and spring 1984 was the first post-strike observation. By spring 1984, ridership had fallen dramatically to its all time low. Since 1984, ridership has rebounded to about 80 percent of its 1980 peak.



**Short-Run and Long-Run Demand Elasticity on the SEPTA Rail System.** Econometric analysis of the SEPTA data reveals that the long-run responses of ridership to changes in prices and service attributes are considerably larger than the short-run responses (see Table 1). Short-run responses—those which occur at the time of the change—all proved to be inelastic; that is, the percentage change in ridership is less than the percentage change in price, number of peak or off-peak trains, or speed of the train. As predicted, the estimated total impacts of changes in prices and service attributes are much larger than the short-run impacts—more than twice as large. The analysis further suggests that about half of the total impact occurs within the first year.

In the case of price, the short-run elasticity is about -0.68, meaning that a 10 percent increase in price generates a 6.8 percent decrease in ridership. This estimate is similar to other measurements of the short-term price elasticity of other commuter systems.<sup>6</sup> The long-run elasticity is almost three times as great, at -1.84. To illustrate how these price elasticities could affect revenues (holding everything else con-

stant), suppose SEPTA, which has about 100,000 riders, increased the average one-way ticket price by \$0.25 or 9.2 percent (Figure 1). Daily revenue would increase immediately by \$8,000 per day. So, because ridership is inelastic in the short run, the transit authority could increase revenues in the short run by increasing fares. But, in the long run, the revenue picture deteriorates. After the first half-year, the increase drops to zero; by the end of the first full year, daily revenue is *reduced* by almost \$6,500, and after four years, revenues are below the original levels by over \$19,000. Since these elasticities work in the opposite way when the fare drops by \$0.25, SEPTA might be able to generate more revenue by lowering prices, provided it can handle the extra passengers.

The budgetary implications of elastic versus inelastic demand are less conclusive in the case of service attributes, since the financial effects of changing the service attributes depend not only on the change in ridership but also on the costs of changing the quality of service. The short-run elasticities for the number of peak trains and the number of off-peak trains are 0.19 and 0.54, respectively, while the short-run speed elasticity is about .24. Since the average number of peak trains in 1986 was 7.6, this implies that an addition of one peak train (a 13 percent increase) will increase peak ridership along that line by 2.6 percent. An additional off-peak train (a 5.3 percent increase) would increase off-peak rider-

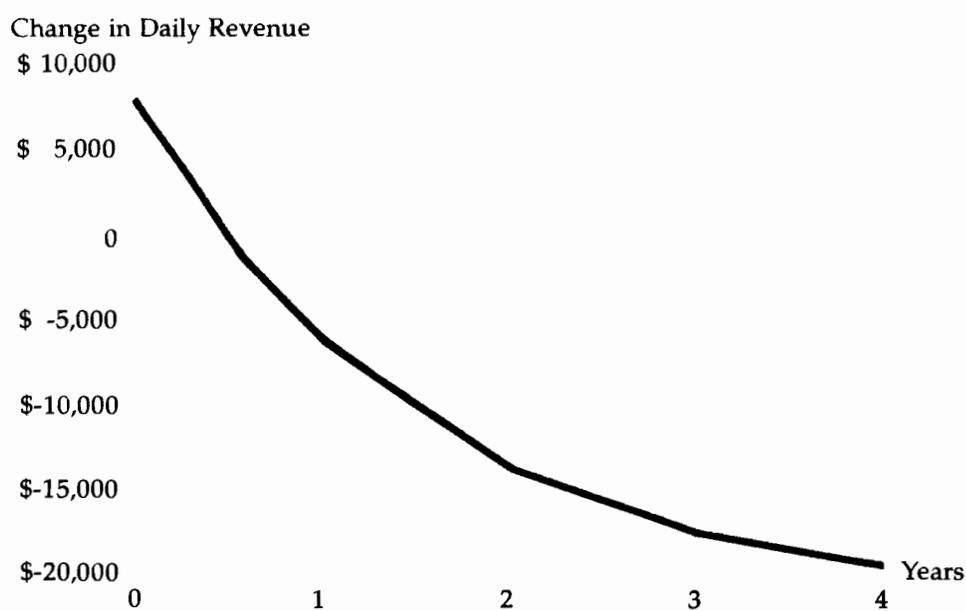
<sup>6</sup>See Clifford Winston, "Conceptual Developments in the Economics of Transportation: An Interpretive Survey," *Journal of Economic Literature*, 23 (1985) pp. 57-94, for estimates of the price elasticity of ridership on the BART commuter rail system in San Francisco.

TABLE 1

	Short Run	Long Run
Average Nominal Price	-0.68	-1.84
Peak Number of Trains	0.19	0.52
Off-peak Number of Trains	0.54	1.47
Speed	0.24	0.66

NOTE: Elasticities are evaluated at 1986 levels and are derived from the coefficients in the Appendix. For example, the short-run price elasticity is:  $\epsilon_0 = (-41.8 \times 5.4) / 333 = -0.68$ . The long-run price elasticity is:  $\epsilon_\infty = (1 / (1 - 0.63)) \times -0.68 = -1.84$ .

FIGURE 1



NOTE: The future revenue impact can be calculated as follows: (1) base year farebox revenue is  $F_0 = p_0 R_0$ , where  $p$  is price and  $R$  is ridership and the subscript denotes the initial period; (2) ridership  $t$  periods after the change in price,  $\Delta p$ , is given by  $R_t = [1 + \epsilon_t (\Delta p / (p + \Delta p))] R_0$  where  $\epsilon_t$  is the  $t$ -period price elasticity; (3) the  $t$ -period price elasticity can be calculated using the formula,  $\epsilon_t = (\epsilon_0 / (1 - \lambda)) (1 - \lambda^{t+1})$ , where  $\epsilon_0$  is the short-run elasticity and  $\lambda$  is the lag parameter (0.63) from the Appendix; (4) the farebox revenue in period  $t$  is  $F_t = R_t (p + \Delta p)$  and the revenue impact is  $F_t - F_0$ . Since each period is about eight months long for the available data, the  $t$  for a one-year impact is 1.5.

ship by 2.8 percent. Likewise, since the average speed of the system in 1986 was 22 miles per hour, increasing average speed by 10 miles per hour (a 45 percent increase) would result in a 10.8 percent increase in ridership. While not as striking as the long-run price elasticity, the long-run implications of service changes are significant as well. The addition of one peak train would increase peak ridership by 7 percent; increasing speed by 10 miles per hour would increase ridership by 29 percent. An increase in speed would tend to have even greater impacts since the authority could operate more trains with no additional equipment or crews. If the greater speed allowed the frequency of service to go up 30 percent, the combined effect on ridership would be an increase greater than 40 percent.

These estimates indicate that there is considerable scope for SEPTA to increase patronage by increasing speed and frequency and lowering price—if the short-run budget constraint could be loosened and if appropriate investments are made by the transit authority to improve service along the dimensions consumers value. Furthermore, price increases and service reductions may be counterproductive in the long run, even if they do balance the budget in the short run. These actions actually may result in a higher subsidy cost per rider or per passenger mile, though the total subsidy may be lower. This is true not only of the SEPTA system, but of any rail system in which price and service changes have relatively small effects on ridership in the short run and relatively large effects in the long run.

### THREE IMPLICATIONS FOR TRANSIT POLICYMAKERS

Three basic policy implications emerge from long-run price and service elasticities that are greater than short-run elasticities. First, transit authorities should closely examine their pricing and service policies to ensure that they are consistent with long-term cost-effective service. This means that the transit authority should actively pursue strategies that encourage development and location decisions that will lead to future ridership.

Second, those who subsidize public transportation should recognize that price increases, service reductions, and uncertainty about the level of future service may have counterproductive effects in the long run. In order to obtain reasonable costs per rider, the subsidy level will have to be large enough to provide service that will induce people to make location and investment decisions that are consistent with public transportation usage. If people are uncertain about the future levels of service, they will insure themselves by becoming less dependent on

public transportation, which will lead to lower future ridership.

Because ridership is more responsive to price and service changes in the long run than in the short run, balancing a transit authority's budget through price increases and service reductions may result in future financial difficulties. The findings based on the analysis of data on one commuter rail system (SEPTA) suggest that the long-term impacts may be sufficiently large that further price increases and reduction in the frequency of trains will not improve a transit authority's long-term financial performance.

Finally, because the consequences of price and service changes are not completely manifest in a single budget year, state and local governments should consider alternatives such as multiyear appropriations. In that case, transit authorities could balance their budgets over a longer period rather than in each budget year. A longer planning horizon would allow transit authorities to avoid making short-run decisions which, in the long run, can lower ridership and increase subsidy costs per rider.

The estimates of elasticities for the SEPTA system reported in this article are derived from a dynamic fixed-effects model. The basic model of ridership from any location consists of two equations:

$$R_j^t = h(p_o^j, p_a^j, A_o^j, A_a^j; D_j^t)$$

$$D_j^t = f(p_o^{j, t-i}, p_a^{j, t-i}, A_o^{j, t-i}, A_a^{j, t-i}; Z_j^{t-i})$$

$$i = 1, 2, \dots, \infty$$

- where:  $R_j^t$  is ridership from location  $j$  in period  $t$ .  
 $p_o^j$  is the price of a trip on the train from  $j$  in period  $t$ .  
 $p_a^j$  is the price of a trip in the car from  $j$  in period  $t$ .  
 $A_o^j$  is the vector of service attributes of the train from  $j$  in  $t$ .  
 $A_a^j$  is the vector of service attributes of the car from  $j$  in  $t$ .  
 $D_j^t$  is a distribution of the characteristics of the population in location  $j$  at time  $t$  which includes the number of people, their destinations, their investments in transportation alternatives, their income, and preferences.  
 $Z_j^t$  is a vector of factors unrelated to transportation affecting  $D$ .

Substituting for D in the first equation, ridership simply becomes a function of current and lagged price and service attributes and a vector of factors unrelated to previous price and service levels which affect ridership only through demographics.

Several assumptions are made to estimate this dynamic model. These are:

- (1) The effects of lagged variables decline geometrically over time.
- (2) The decay rate is the same for each explanatory variable.
- (3) Attributes of car travel, except for price, are unchanged during the sample period.
- (4) Demographic differences across locations (which may be the result of differing prior levels and price of transportation) which give rise to different mean ridership levels across locations can be adequately represented by "fixed effects," meaning that we can use dummy variables for each location.
- (5)  $Z^{it}$  is uncorrelated with the transportation variables and so can be disregarded when estimating the impacts of price and service changes.

Given these assumptions, the following equation can be estimated:

$$R^{it} = \lambda R^{i,t-1} + \alpha_1 p_o^{it} + \alpha_2 p_a^{it} + \alpha_3 A_o^{it} + \delta D + e$$

where  $\lambda$  is the geometric lag parameter and D is a vector of dummy variables for location. In the actual regression, dummy variables for years 1984 and 1985 which immediately followed a 3-month strike by SEPTA workers are included as well. The  $\alpha$ 's give the short-run impact of the variable, while the term  $\alpha/(1-\lambda)$  gives the total impact. The mean lag is  $\lambda/(1-\lambda)$ . The model has been estimated with an asymptotic equivalent of maximum likelihood.

The data set consists of data on 129 of the 165 stations served by SEPTA for twelve observation periods between 1978 and 1986. In addition, the cost of operating, owning and parking a car have been added to the SEPTA data.

The estimation results are presented below. The prices used in the estimation are nominal. The results all conform to what is expected theoretically, and generally the estimated coefficients are highly significant, including those on the lag parameter. The "truncation parameter" is a necessary artifact of the maximum likelihood estimation used here.

### Estimation Results: Full Sample, Nominal Prices

Independent Variable	Coefficient	Standard Error	1986 Mean
Lagged Ridership	0.63	0.04	287.2
Peak Number of Trains	5.8	1.6	7.6
Off-peak Number of Trains	3.1	0.6	18.9
Price	-41.8	5.3	5.4
Speed	3.7	1.0	22.0
Variable Cost of Auto Trip	48.8	7.9	8.1
Fixed Cost of Auto Ownership	12.9	6.3	7.1
1984	-81.8	8.7	0.083
1985	-32.5	9.0	0.083
Truncation Parameter	65.8	14.0	
Number of Observations	1548		
Mean Square Error	7945.2		
Mean Lag	1.7		

NOTE: The average time period is eight months, so the mean lag of 1.7 can be converted to 13.6 months. The dependent variable is ridership per station; its mean for the whole sample is 349. The mean for 1986 was 333.

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