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Valuing Rail Transit:
Comparing Capital and Operating Costs to Consumer Benefits

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Abstract

A certain acrimony pervades the longstanding debate over the costs and benefits of public rail transportation in the United States. Some seem opposed to all rail transit all the time, while others support any and every rail project, despite sometimes high costs and low ridership. With much of the debate focused on pricing automobile externalities, transportation choice, and the rail's external benefits, surprisingly few studies assess which rail transit systems create net positive social welfare. If consumer benefits alone do not justify the high cost of a transit investment, what would the external value of a passenger trip have to be to do so?

Combining fare, ridership, operating, and capital cost data for 24 transit agencies' heavy and/or light rail systems, this paper makes back-of-the-envelope estimates of how transit systems' rider benefits compare to operating deficits. Urban rail systems may not be optimal from a transportation systems or economic cost-benefit perspective, but they clearly create value for consumers and society. Given a low, but commonly applied, elasticity of -0.3 and a linear demand curve, two transit systems create net social welfare gains based solely on consumer surplus. At least ten others likely provide net benefits when accounting for economic externalities. At an elasticity of -0.6, no system provides net social welfare gains without accounting for externalities. At least five systems are unlikely to provide net economic benefits, even given generous assumptions about external and rider benefits.

INTRODUCTION

A certain acrimony pervades the longstanding debate over the costs and benefits of public rail transit in the United States. There are those, who argue that bus, enhanced bus, and bus rapid transit are almost always a superior investment (*1*). "Bus Good, Train Bad", as Glaeser (*2*) summed up a caricature of the school of thought. Some seem opposed to all public transit, all the time, whether bus or rail (*3*). Others appear to support any and every rail project, no matter the cost (*4*). With much of the debate focused on automobile externalities, transportation choice, and the external benefits of transit, surprisingly few studies have attempted to gauge which transit systems create positive social welfare. If consumer welfare alone does not, what would the external benefits have to be to justify the high cost of a transit system?

Combining fare, ridership, operating, and capital cost data for 24 transit agencies' heavy and/or light rail systems, this paper makes back-of-the-envelope estimates of how rider benefits compare to costs. While transit systems may not be optimal from a transportation systems or economic cost-benefit perspective, they clearly create consumer and social value. Does the value of transit systems outweigh their costs? Sometimes yes; sometimes no. Given a low, but commonly applied, elasticity of -0.3 and a linear demand curve, two transit systems provide net social welfare gains based solely on consumer surplus. At least ten others likely provide net economic benefits when accounting for externalities. At an elasticity of -0.6, no system produces net benefits without accounting for externalities. At least five systems are unlikely to provide net economic benefits, even given generous assumptions about external and consumer benefits.

Policy Context

Since the opening of BART (Bay Area Rapid Transit System) in 1972, new heavy rail systems have been constructed in five other American cities and San Juan, Puerto Rico. New light rail systems have opened in dozens of other cities. Unlike with many earlier rail systems in America, public dollars—whether federal, state, or local—covered nearly all of the investment costs and continue to provide operating subsidies. From the outset, these rail projects have been criticized for failing to attract enough riders to pay for themselves. Just four years after its opening, Webber (*5*) declared that BART failed to deliver on every one of its objectives—particularly in regards to strengthening the core city, giving order to the suburbs, and eliminating congestion. One influential study found that projections systematically overestimated benefits while underestimating costs (*6*), although projections have improved since the 1970s and 80s. Rail transit has continued to expand, despite the criticism that many projects fail to justify their costs. Understanding where and how urban rail investments achieve net social welfare gains is essential to targeting future investments and improving the performance of existing ones.

TRANSIT RIDER BENEFITS

There is a wide literature on how to conduct transportation cost-benefit analyses. A common approach multiplies users' predicted time savings by their values of time and sums the results to estimate user benefits (*7*). For transit, measuring and valuing time savings is more complicated. Service reliability, cleanliness, schedule frequency, access and egress times, and transfers play significant roles in how people value transit (*8*). While these transit system attributes can be converted to time savings or monetary values, an alternative approach makes estimates using fare elasticity and other assumptions about demand for transit.

Holding other system and non-system (ie weather, cost of substitutes, etc.) attributes constant, fare elasticity measures the proportional change in riders (or rider miles) caused by an incremental change in fare. As fares go up, fewer riders take transit. Knowing the general shape of the demand curve, the number of riders, the fare, and the fare-elasticity, it is possible to estimate consumer surplus—the difference between all fares paid for trips and all travelers' willingness to pay for those trips.

Although it is difficult, if not impossible, to know the exact shape of the demand curve, there is a wide body of empirically derived knowledge on transit fare elasticity. Over four decades of empirical research have generally found that transit demand is price inelastic: A percent change in transit fares corresponds to a smaller proportional change in ridership. A common rule of thumb, the Simpson-Curtin rule, puts transit elasticity at around -0.33—a 1% increase in fares leads to a 0.33% decrease in ridership. Fare elasticities, however, vary tremendously at different price points and in different cities and circumstances (*9*). They also vary in the short term and the long term, with long term elasticities often estimated at twice the elasticity of the short term, as travelers make decisions about where to live and work and whether to purchase a car (*10*). The Transportation Cooperative Research Program found that larger cities tend to have more inelastic demand for rail transit, probably as a result of higher parking and congestion costs (*11*). Work, peak hour, and transit-dependent trips also have less elastic demand than non-work, non-peak, and transit-choice trips respectively. Fare elasticity also varies by trip length, mode (bus is generally more elastic), and the type of fare (monthly pass, single fare, student pass, senior). Few American studies find rail fare elasticities that are below -0.25 or above -1.0, although there are exceptions.

Transportation Cost-Benefit Analysis: Externalities

In general, transit externalities fall into two categories: those related to the mode and those related to the external costs of automobile travel. The former includes constant increasing returns to scale for transit. Given transit's high up-front investment costs, the marginal cost of providing service for an additional rider is generally lower than the average cost, particularly at non-peak hours, when track and rolling stock are used less heavily. Transit riders also confer small benefits on one another, since agencies respond to demand by increasing transit frequency, which benefits all riders.

The majority of the external benefits of transit, however, relate to the external costs of automobile trips. If congestion were priced properly, there would be no microeconomic argument to provide HOV lanes or subsidize transit to reduce congestion (*12*). As is, however, cities benefit by diverting drivers into fewer vehicles and transit. Congestion is widely thought by economists to be the greatest external cost of auto travel. According to the Texas Transportation Institute, public transportation in the 90 largest American urban areas, saved drivers over $13 billion in delay hours and wasted fuel in 2007 due to congestion, the total costs of which were estimated at $75 billion (*13*). These figures, however, do not distinguish between economically inefficient congestion, related to mispricing, and the “healthy” congestion of high demand. They also assume that all transit trips would otherwise be taken by automobile and treat monetary transfers from drivers to gas stations and government as social costs.

Pollution, fatalities, injuries, and spatial distortions in land settlement patterns are also negative externalities of automobile travel. Despite lower values, these externalities may contribute greatly to the social benefits of transit investments. Stokes et al. (*14*) estimate the public health benefits of the Charlotte light rail system at $12.6 million over 9 years. While the authors note that this amount is quite small in comparison to costs, the annual savings equal almost 6% of the system's annualized capital and operating costs, approximately $0.11 per rail passenger mile.

Parry et al. (*15*) estimate the national average external cost per automobile mile at $0.11—$0.05 are attributed to congestion, $0.03 to accidents, $0.02 to local pollution, and $0.01 to global warming and oil dependency. Congestion and local pollution costs, however, are higher in the dense urban areas served by transit. Parry and Small (*16*) find the marginal external cost of a passenger mile of automobile travel accounting for congestion, pollution, and accidents minus fuel tax offsets, to be $0.25 for Washington, D.C. and $0.31 for Los Angeles during the peak and under $0.10 during the off-peak.

Recent Studies

At least three recent studies use the National Transit Database (NTD) to conduct cost-benefit analyses of existing transit systems. The NTD collects and distributes agency-reported annual data on transit fares, ridership, operational costs and expenditures, funding sources, and capital expenditures by mode and transit agency since 1992. Harford (*17*) estimates benefit-cost ratios for rail and bus transit systems in 81 urbanized areas in the United States by weighing congestion savings and user benefits against annual capital and operating costs. Capital costs are assumed to be 1.4 and 1.2 times the annual operating costs for rail and bus respectively. He calculates user benefits based on linear fare elasticities ranging from -0.15 and -0.45 and congestion savings based on the Texas Transportation Institute's 2004 Urban Mobility Report. The author finds a range of transit-attributed congestion savings per passenger mile of transit that range from $0.05 in Anchorage, AK to $0.87 in Los Angeles, CA. With an elasticity of -0.3 and congestion savings valued at 90% of the Texas Transportation Institute's estimates, 23 out of 81 systems have positive benefit-cost ratios. Given the larger size of the high performing systems, the overall benefit to cost ratio is a healthy 1.34. The top performing systems are Atlanta, Los Angeles, Houston, Washington DC, and San Diego.

Winston and Maheshri (*18*) use panel data from the NTD and several other sources to estimate the social welfare of light and heavy rail transit systems in 25 metropolitan areas. Using the NTD's figures on passenger miles, fares and household income, they estimate demand elasticities, consumer surplus, and transit agency deficits. Adding the external congestion costs of additional drivers on the road in the absence of the transit system and subtracting annual capital and operating costs, they find that only one system, BART, increases social welfare. The other systems create a net annual loss of over $4.5 billion (in 2000 dollars).

Parry and Small (*16*), using the same NTD database, develop an analytic model to estimate the optimal marginal price for transit, while accounting for congestion, pollution, accidents, and transit’s economies of scale. They find the large current transit subsidies more than justified and conclude that reducing fares below 50% of operating costs generally improves net social welfare. Derived optimal subsidies for Los Angeles and Washington, DC equal more than 90% of operating costs during the peak hours and 88% during off-peak hours. Previous studies reviewed by the authors estimate the appropriate subsidy between 0% and more than100% of operating costs; a wide range. The authors, however, do not include capital costs and caution that drawing transit riders by constructing new lines probably costs significantly more per passenger mile than the marginal benefits.

RESEARCH APPROACH AND DATASET

This paper uses the same NTD database, but contributes additional capital cost data and analyzes the various assumptions that result in the papers' substantially different findings, despite reliance on the same primary source. Rather than quantifying the external benefits of transit, the paper estimates what the average external benefits of a passenger mile of transit would have to be in order to have a net economic benefit. Although this provides general insight into which rail systems are likely to produce net social benefits, more detailed and specific analysis is needed to determine the costs of reasonable counterfactual scenarios without rail transit. Estimating the social costs of closing the subway in New York City is well beyond the scope of this study.

Cost and Benefit Data

Data on operating costs, fares passenger trips and passenger miles, come from the 2008 NTD Data for Systems database. The NTD provides these estimates by agency, mode, and service provider (whether operations are provided by the agency or a private entity). Data for agencies that provide both heavy and light rail transit were summed together. All costs are in 2009 dollars, adjusted using the Bureau of Labor Statistics Consumer Price Index (CPI) Online Calculator. Several governmental and consultant provide data on the initial investment costs for different transit systems and corridors (*19*). Although construction costs have escalated more quickly than inflation, I opt to adjust costs with the CPI to reflect more closely the current value of dollars spent in the past.

Recent urban rail systems in Seattle and Phoenix are not included in this study, since they have yet to provide data to the NTD. For the 24 systems, investment costs are available for 100% of nine systems, more than 80% (by number of stations in the investment) for a further nine, and 53% for one system. Percent of stations gives a better approximation than guideway or track miles of the percent of total costs, since construction is more expensive in central rather than outlying areas, where stations are farther apart.

After adjusting all capital costs into 2009 dollars and dividing incomplete systems by the percent of costs available (i.e. if data are available for 80% of a transit system, these data are adjusted, summed, and divided by 0.8), I annualize costs using the Office of Budget and Management's (*20*) 10-year bond real discount rate of 2.2% over 50 years. The choice of discount rate is always somewhat subjective, but a high discount rate would exaggerate capital costs relative to annual operating costs, fares, and benefits, since these are not projected into the future and discounted into present value. The Federal Transit Administration provides guidance on the active service life of different aspects of capital investments, ranging from 25 year for vehicles to 125 years for right-of-way. Looking at the detailed capital expenditures of 19 light rail and 17 heavy rail investments, their average service life ranges from 48 to 52 years, depending on the service life assigned to soft costs.

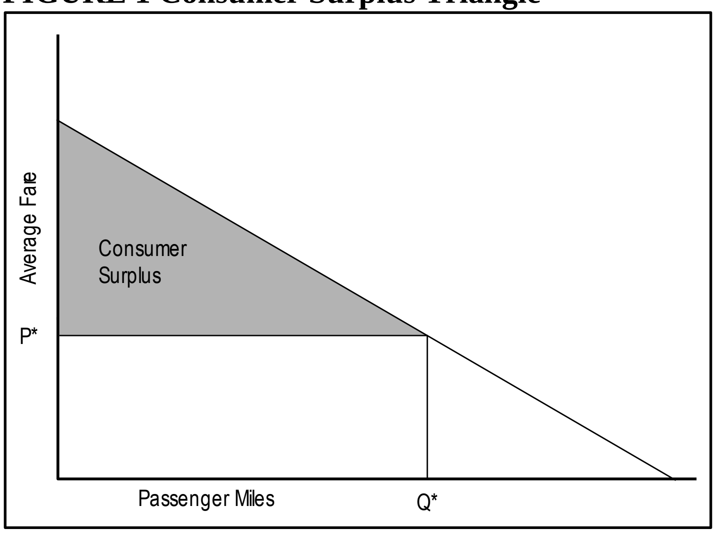
In order to estimate capital costs for five systems where less than 10% of date initial were available, I average 17 years of 2009-adjusted capital expenditure data from the NTD. Since these five systems are all over 30 years old, capital depreciation will likely cause agencies to reinvest in capital at roughly the same annualized cost as the initial system over a number of years. Testing this hypothesis, I compare costs using both methods for the two oldest systems with significant available capital cost data. For the BART, amortizing the initial capital investment at 2.2% over 50 years gives an annual capital cost estimate of $321 million, compared to $355 million, using the average capital expenditure from 1992 to 2008; for Washington, D.C., the estimates are $694 million and $425 million.

Although, using the NTD's capital expenditure data is imperfect and should not be used for newer systems, it provides reasonable estimates and allows the inclusion of the rail systems in New York, Philadelphia, Chicago, Boston, and San Francisco—some of the nation's largest. I further adjust the capital cost estimates for these systems by a factor of 1.27, the average difference in capital costs using the two estimation methods for BART and the Washington, D.C. Metro. This methodology requires two additional caveats. The different systems have had varying levels of system expansion since 1992, which would affect capital expenditure levels. Furthermore, construction costs have increased relative to inflation and the cost of capital replacement may be higher than the initial investment costs.

Estimating Rider Benefits

I use a simple back-of-the-envelope calculation to estimate consumer benefits as the triangle shape created by three points: the observed average fare and annual passenger trips, the observed fare and zero passenger trips, and the fare at which no passenger trips are expected given a linear demand function and fare elasticities of -0.3, -0.6, and -1.0. Figure 1 shows the relationship between a linear demand curve, the price and quantity of transit consumed and consumer surplus. P* and Q* are respectively the average fare and passenger miles travelled, as reported for 2008 in the NTD.

FIGURE 1 Consumer Surplus Triangle



Linear demand curves will tend to underestimate consumer benefits; an absolute $0.25 fare increase has the same effect on ridership whether it increases fares by 10% or doubles them. The expected change would likely be smaller and more related to the percentage change than the absolute change in price. Although a simplification with a bias toward underestimation, linear demand curves simplify calculations and prevent any gross overestimates of the consumer surplus attributable to the people who value transit most highly. Assuming a constant point elasticity, where ridership responds to percent rather than absolute increases in fares, gives extraordinary weight to the consumer surplus of riders on the left side of the demand curve, where the curve slopes sharply upward.

TABLE 1 Rail Agency Annual Costs, Revenues, and Deficits

City	Agency	Unlinked Passenger Trips (000s)	Passenger Miles (000s)	Average Trip Length	Fare Revenues (000s)	Operating Expenses (000s)	Capital Costs (000s)	Annual Deficit (000s)	Deficit per Trip	Deficit per Mile
Atlanta	Metropolitan Atlanta Rapid Transit Authority	82.984	593.419	7.2	$49.242	($158.545)	($239.874)	($349.176)	($4.21)	($0.59)
Baltimore	Maryland Transit Administration	21.810	120.898	5.5	$19.176	($92.433)	($94.194)	($167.451)	($7.68)	($1.39)
Boston	Massachusetts Bay Transportation Authority	222.430	736.938	3.3	$230.793	($397.975)	($266.901)*	($434.084)	($1.95)	($0.59)
Buffalo	Niagara Frontier Transportation Authority	5.681	14.623	2.6	$4.244	($23.440)	($31.538)	($50.734)	($8.93)	($3.47)
Charlotte	Charlotte Area Transit System	2.263	13.065	5.8	$1.623	($9.495)	($14.214)	($22.087)	($9.76)	($1.69)
Chicago	Chicago Transit Authority	198.137	1,183.981	6.0	$203.810	($439.881)	($433.735)*	($669.806)	($3.38)	($0.57)
Dallas	Dallas Area Rapid Transit	19.438	151.755	7.8	$13.823	($89.218)	($59.686)	($135.081)	($6.95)	($0.89)
Denver	Denver Regional Transportation District	20.635	134.036	6.5	$21.946	($41.677)	($47.604)	($67.335)	($3.26)	($0.50)
Los Angeles	Los Angeles County Metropolitan Transportation Authority	86.707	524.813	6.1	$61.532	($249.196)	($350.159)	($537.823)	($6.20)	($1.02)
Miami	Miami-Dade Transit	18.539	142.152	7.7	$13.247	($82.382)	($82.226)	($151.362)	($8.16)	($1.06)
Minneapolis	Metro Transit	10.222	61.059	6.0	$8.990	($23.698)	($15.078)	($29.785)	($2.91)	($0.49)
Newark/Jersey City/Trenton	New Jersey Transit Corporation	21.331	97.029	4.5	$20.976	($114.560)	($132.790)	($226.374)	($10.61)	($2.33)
New York	MTA New York City Transit	2,428.309	9,998.115	4.1	$2,176.131	($3,250.031)	($2,446.748)*	($3,520.648)	($1.45)	($0.35)
Philadelphia	Southeastern Pennsylvania Transportation Authority	121.562	484.989	4.0	$106.007	($211.127)	($257.056)*	($362.177)	($2.98)	($0.75)
Pittsburgh	Port Authority of Allegheny County	7.142	33.256	4.7	$7.054	($44.345)	($51.127)	($88.418)	($12.38)	($2.66)
Portland	Tri-County Metropolitan Transportation District of Oregon	38.932	193.574	5.0	$31.495	($84.120)	($76.891)	($129.516)	($3.33)	($0.67)
Sacramento	Sacramento Regional Transit District	15.485	85.807	5.5	$14.032	($51.830)	($29.969)	($67.767)	($4.38)	($0.79)
Salt Lake City	Utah Transit Authority	14.753	71.121	4.8	$9.797	($27.383)	($24.614)	($42.200)	($2.86)	($0.59)
San Diego	San Diego Metropolitan Transit System	37.621	206.924	5.5	$31.120	($55.949)	($71.009)	($95.838)	($2.55)	($0.46)
San Francisco	San Francisco Bay Area Rapid Transit District	115.228	1448.529	12.6	$308.852	($478.987)	($321.281)	($491.416)	($4.26)	($0.34)
San Francisco	San Francisco Municipal Railway	122.707	239.057	1.9	$68.723	($278.018)	($180.962)*	($390.256)	($3.18)	($1.63)
San Jose	Santa Clara Valley Transportation Authority	10.451	54.475	5.2	$8.598	($55.544)	($82.582)	($129.529)	($12.39)	($2.38)
San Juan	Puerto Rico Highway and Transportation Authority	8.700	44.784	5.1	$10.466	($57.500)	($76.147)	($123.181)	($14.16)	($2.75)
Washington, DC	Washington Metropolitan Area Transit Authority	288.040	1639.629	5.7	$458.305	($755.747)	($693.685)	($991.128)	($3.44)	($0.60)

* Costs estimated using NTD capital expenditure data.

Although fare elasticity and the shape of the demand curve vary by system, using the same elasticity for each system prevents small measurement errors from creating large estimation errors. As this paper finds, the large, congested cities expected to have the most inelastic transit demand already tend to outperform cities expected to have more elastic demand. Empirically estimated elasticities will likely increase the performance gap. Table 1 presents the data from which the cost-benefit analyses are derived. Annual transit deficits, the difference between fares collected and operating and capital costs, range from $0.34 for BART to $3.47 per passenger mile for the Buffalo light rail system. By trip, New York City has the lowest deficit, while San Juan has the highest.

RAIL TRANSIT CONSUMER SURPLUS

Table 2 presents figures on consumer surplus and economic welfare losses from transit at elasticities of -0.3, -0.6, and -1.0, *if externalities are not included*. The columns labeled "net gain per trip" and "net gain per passenger mile" provide the targets for how much amount external benefit a transit system would need to generate in order to create net economic benefits. At an elasticity of -0.3, the benefits of two systems, the New York subway and BART, outweigh their costs without accounting for any externalities. Respectively, they create a social surplus of $106 and $23 million per year. At a $0.07 and $0.14 loss per passenger mile, the Boston and Washington, D.C. subways come close to justifying their costs without counting congestion, environmental or health benefits. Five systems—Buffalo, New Jersey, Pittsburgh, San Jose, and San Juan—appear unlikely to provide net social benefits, even allowing for rather large social external benefits. At higher elasticities, systems perform less well and no system economically justifies its costs solely on user benefits. Even at unit elasticity, eight of the 24 systems provide net benefits, given social external benefits of $0.50 per passenger mile. Depending on the elasticity, the total rider benefits of the 24 systems range from $2 billion to $6.5 billion.

As expected, systems in large, dense cities tend to outperform the smaller ones. Not only do rail's economies of scale favor high ridership, density tends to increase the parking and congestion costs of transit's primary competitor, the private automobile. The noticeable exceptions are Los Angeles, which has higher costs and fewer riders than several smaller cities, and the San Francisco light rail, which operates frequently in mixed traffic, significantly increasing operating costs per passenger mile. This system has operating losses per passenger mile ($0.88) that are nearly identical to the bus systems in New York ($0.86), Boston ($0.88), and Washington, D.C. ($0.91). Of the newer light rail systems, the top performers are San Diego, Denver, Minneapolis, Salt Lake City, and Portland.

Using empirically derived elasticities may influence the rankings, but, in general, will reinforce the performance trends shown below. Transit systems in larger, denser cities with longer average trips, and higher congestion levels, are likely to produce greater consumer surplus. The same holds for external benefits. An additional car mile in Manhattan creates more congestion than one in Buffalo.

TABLE 2 Consumer Surplus and Welfare Loss per Trip and per Passenger Mile (without Externalities)

		Elasticity = -0.3				Elasticity = -0.6		Elasticity = -1.0	
City	Agency	Consumer Surplus (000s)	Net Economic Gain (000s)	Net Gain per Unlinked Trip	Net Gain per Mile	Net Gain per Unlinked Trip	Net Gain per Mile	Net Gain per Unlinked Trip	Net Gain per Mile
Atlanta	Metropolitan Atlanta Rapid Transit Authority	$82,070.75	($267,105.340)	($3.22)	(0.45)	(3.71)	(0.52)	(3.91)	(0.55)
Baltimore	Maryland Transit Administration	$31,959.75	($135,491.630)	($6.21)	(1.12)	(6.95)	(1.25)	(7.24)	(1.31)
Boston	Massachusetts Bay Transportation Authority	$384,654.67	($49,429.392)	($0.22)	(0.07)	(1.09)	(0.33)	(1.43)	(0.43)
Buffalo	Niagara Frontier Transportation Authority	$7,073.30	($43,660.539)	($7.69)	(2.99)	(8.31)	(3.23)	(8.56)	(3.32)
Charlotte	Charlotte Area Transit System	$2,704.69	($19,382.039)	($8.57)	(1.48)	(9.16)	(1.59)	(9.40)	(1.63)
Chicago	Chicago Transit Authority	$339,682.59	($330,123.638)	($1.67)	(0.28)	(2.52)	(0.42)	(2.87)	(0.48)
Dallas	Dallas Area Rapid Transit	$23,037.78	($112,043.167)	($5.76)	(0.74)	(6.36)	(0.81)	(6.59)	(0.84)
Denver	Denver Regional Transportation District	$36,576.62	($30,758.690)	($1.49)	(0.23)	(2.38)	(0.37)	(2.73)	(0.42)
Los Angeles	Los Angeles County Metropolitan Transportation Authority	$102,553.99	($435,269.335)	($5.02)	(0.83)	(5.61)	(0.93)	(5.85)	(0.97)
Miami	Miami-Dade Transit	$22,077.57	($129,284.278)	($6.97)	(0.91)	(7.57)	(0.99)	(7.81)	(1.02)
Minneapolis	Metro Transit	$14,983.10	($14,802.111)	($1.45)	(0.24)	(2.18)	(0.37)	(2.47)	(0.41)
Newark/Jersey City/Trenton	New Jersey Transit Corporation	$34,960.69	($191,413.504)	($8.97)	(1.97)	(9.79)	(2.15)	(10.12)	(2.22)
New York	MTA New York City Transit	$3,626,885.34	$106,237.724	$0.04	0.01	(0.70)	(0.17)	(1.00)	(0.24)
Philadelphia	Southeastern Pennsylvania Transportation Authority	$176,677.89	($185,498.677)	($1.53)	(0.38)	(2.25)	(0.56)	(2.54)	(0.64)
Pittsburgh	Port Authority of Allegheny County	$11,757.02	($76,660.755)	($10.73)	(2.31)	(11.56)	(2.48)	(11.89)	(2.55)
Portland	Tri-County Metropolitan Transportation District of Oregon	$52,492.25	($77,023.471)	($1.98)	(0.40)	(2.65)	(0.53)	(2.92)	(0.59)
Sacramento	Sacramento Regional Transit District	$23,387.19	($44,379.378)	($2.87)	(0.52)	(3.62)	(0.65)	(3.92)	(0.71)
Salt Lake City	Utah Transit Authority	$16,327.65	($25,872.239)	($1.75)	(0.36)	(2.31)	(0.48)	(2.53)	(0.52)
San Diego	San Diego Metropolitan Transit System	$51,866.95	($43,971.373)	($1.17)	(0.21)	(1.86)	(0.34)	(2.13)	(0.39)
San Francisco	San Francisco Bay Area Rapid Transit District	$514,753.82	$23,338.233	$0.20	0.02	(2.03)	(0.16)	(2.92)	(0.23)
San Francisco	San Francisco Municipal Railway	$114,538.57	($275,717.768)	($2.25)	(1.15)	(2.71)	(1.39)	(2.90)	(1.49)
San Jose	Santa Clara Valley Transportation Authority	$14,329.37	($115,199.389)	($11.02)	(2.11)	(11.71)	(2.25)	(11.98)	(2.30)
San Juan	Puerto Rico Highway and Transportation Authority	$17,443.31	($105,737.609)	($12.15)	(2.36)	(13.16)	(2.56)	(13.56)	(2.63)
Washington, DC	Washington Metropolitan Area Transit Authority	$763,841.55	($227,286.329)	($0.79)	(0.14)	(2.12)	(0.37)	(2.65)	(0.46)

Comparing Results with Previous Studies

Applying different elasticities contributes to variation in the results of studies using the NTD to estimate the social welfare of transit systems. The Winston and Maheshri paper (*18*), which finds only one transit system to create positive social welfare, applies elasticities that range from -0.97 to -5.4, far higher than other estimates. An elastic demand, furthermore, suggests that most transit operators could increase revenues by lowering fares. In New York City, the author's derived consumer surplus implies that the average consumer surplus from the subway is around $0.10 per passenger. Given the linearity of their demand functions and an estimated elasticity of -1.3 increasing fares by around 75% would completely eliminate subway ridership in New York. By contrast Parry and Small (*16*) estimate peak elasticities at -0.24 and off-peak at -0.48. Harford uses a range of elasticities from -0.15 to -0.45. Despite these differences, Winston and Maheshri's consumer surplus estimates often exceed those of other studies. Table 3 compares their results to findings from this paper.

The four studies also rely on different, capital costs, estimation techniques, and years of data. As a result, the authors find different annual transit deficits and external congestion benefits. In sharp contrast with Parry and Small, Winston and Maheshri find that the marginal cost of an additional passenger mile of transit is higher than the average cost in New York City and nearly equal in the other cities studied. This indicates that there are no economies of scale for rail transit. In terms of capital costs, Winston and Maheshri's exclude the cost of right-of-way acquisitions, but exceed this study's estimates of transit deficits by 68% per system on average, after adjusting into 2009 dollars. Since net operating losses are available from the NTD, differences in capital cost estimation account for the majority of the variation. Their estimates for New York, San Francisco light rail and Washington D.C.'s deficits are 80% to 90% of this paper's, while New Jersey Transit's deficits are just 30%. Half of the systems have higher consumer surplus estimates; half have lower. In some cases, such as Atlanta, Chicago, and BART, Winston and Maheshri give consumer surplus estimates that are more than four times as high as this paper's low estimates, despite using similar elasticities. The substantive reason for this difference is not apparent. For some systems, the impacts are quite pronounced. In Denver, they estimate agency deficits two times higher than and consumer benefits of less than a quarter of this paper.

The top two transit systems in Harford's cost-benefit analysis (*17*), Atlanta and Los Angeles, have respectively the 12th and 15th (out of 24) lowest ratio of consumer surplus to costs in this study. This difference comes primarily from four factors. First, Los Angeles has the highest valued congestion benefit for each passenger mile of transit, while Atlanta's is above average. Second, Harford does not explicitly account for differences in the benefits of rail and bus passenger miles; he assumes a uniform elasticity, despite findings that rail elasticities are significantly lower than bus. In 2008, the percent of public transit passenger miles traveled on fixed guideway service was 30% and 61% respectively for the Los Angeles and Atlanta regions, compared to 82% for Boston, 80% for New York, 74% for San Francisco, 73% for Chicago, and 70% for Washington, D.C. Third, Los Angeles and Atlanta account for two of the four rail systems, where capital costs per passenger mile are higher than operating costs. The other two, San Jose and Pittsburgh are at the bottom of the rankings in both studies. By applying a uniform ratio of 1.4 times operating costs to estimate capital costs, Harford underestimates capital costs on these systems. Finally, Atlanta and Los Angeles have respectively the first and third best performing bus systems of the 24 systems in this study on an operating loss per passenger mile basis.

TABLE 3 Comparing Differences in Agency Deficit and Consumer Surplus Estimates

		Annual deficits (in Millions of 2009 dollars)			Consumer Surplus (in millions of 2009 dollars)		
City	Agency	Winston and Maheshri (2007)*	This paper	Percent Difference	Winston and Maheshri (2007)	This paper (low estimate)	Percent Difference
Atlanta	Metropolitan Atlanta Rapid Transit Authority	$530.00	$349.18	151.79%	$150.00	$24.62	609.23%
Baltimore	Maryland Transit Administration	$247.50	$167.45	147.80%	$7.50	$9.59	78.22%
Boston	Massachusetts Bay Transportation Authority	$876.25	$434.08	201.86%	$320.00	$115.40	277.31%
Buffalo	Niagara Frontier Transportation Authority	$64.00	$50.73	126.15%	$2.50	$2.12	117.81%
Chicago	Chicago Transit Authority	$805.00	$669.81	120.18%	$488.75	$101.90	479.61%
Dallas	Dallas Area Rapid Transit	$553.75	$135.08	409.94%	$16.25	$6.91	235.12%
Denver	Denver Regional Transportation District	$323.75	$67.34	480.80%	$2.50	$10.97	22.78%
Los Angeles	Los Angeles County Metropolitan Transportation Authority	$596.25	$537.82	110.86%	$21.25	$30.77	69.07%
Miami	Miami-Dade Transit	$176.25	$151.36	116.44%	$2.50	$6.62	37.75%
Newark/Jersey City/Trenton	New Jersey Transit Corporation	$68.88	$226.37	30.43%	$2.50	$10.49	23.84%
New York	MTA New York City Transit	$3,125.00	$3,520.65	88.76%	$1,062.50	$1,088.07	97.65%
Philadelphia	Southeastern Pennsylvania Transportation Authority	$456.25	$362.18	125.97%	$67.50	$53.00	127.35%
Pittsburgh	Port Authority of Allegheny County	$158.75	$88.42	179.55%	$2.50	$3.53	70.88%
Portland	Tri-County Metropolitan Transportation District of Oregon	$266.25	$129.52	205.57%	$5.00	$15.75	31.75%
Sacramento	Sacramento Regional Transit District	$120.88	$67.77	178.37%	$2.50	$7.02	35.63%
San Francisco	San Francisco Bay Area Rapid Transit District	$780.00	$491.42	158.73%	$655.63	$154.43	424.56%
San Francisco	San Francisco Municipal Railway	$345.00	$390.26	88.40%	$3.75	$34.36	10.91%
San Jose	Santa Clara Valley Transportation Authority	$252.50	$129.53	194.94%	$2.50	$4.30	58.16%
Washington, D.C.	Washington Metropolitan Area Transit Authority	$821.25	$991.13	82.86%	$351.25	$229.15	153.28%

*Estimates do not include the authors' 10.2% exhaustive public spending cost.

The cost and performance of bus service is particularly important when comparing a counterfactual scenario of no rail transit. With the exception of Buffalo, New Jersey Transit, and Baltimore, the average operating loss per passenger mile of rail is lower than the loss per passenger mile of bus. This results in part from rail operating on the most transit-friendly corridors. Rail, however, also has economies of scale at higher passenger volumes and is generally less affected by traffic congestion than bus. When rail provides passenger miles more cheaply than bus, transit agencies save money by switching to rail.

TABLE 4 Rail and Bus Net Operating Losses per Passenger Mile

City	Rail Agency	Rail: Net Operating Loss	Bus: Net Operating Loss	Operating Loss Difference
Atlanta	Metropolitan Atlanta Rapid Transit Authority	$0.18	$0.24	($0.06)
Baltimore	Maryland Transit Administration	$0.61	$0.56	$0.04
Boston	Massachusetts Bay Transportation Authority	$0.23	$0.88	($0.65)
Buffalo	Niagara Frontier Transportation Authority	$1.31	$0.88	$0.43
Charlotte	Charlotte Area Transit System	$0.60	$0.71	($0.10)
Chicago	Chicago Transit Authority	$0.20	$0.62	($0.42)
Dallas	Dallas Area Rapid Transit	$0.50	$1.11	($0.62)
Denver	Denver Regional Transportation District	$0.15	$0.58	($0.43)
Los Angeles	Los Angeles County Metropolitan Transportation Authority	$0.36	$0.46	($0.10)
Miami	Miami-Dade Transit	$0.49	$0.62	($0.14)
Minneapolis	Metro Transit	$0.24	$0.49	($0.25)
Newark/Jersey City/Trenton	New Jersey Transit Corporation	$0.96	$0.41	$0.55
New York	MTA New York City Transit	$0.11	$0.86	($0.75)
Philadelphia	Southeastern Pennsylvania Transportation Authority	$0.22	$0.62	($0.40)
Pittsburgh	Port Authority of Allegheny County	$1.12	$0.78	$0.34
Portland	Tri-County Metropolitan Transportation District of Oregon	$0.27	$0.79	($0.52)
Sacramento	Sacramento Regional Transit District	$0.44	$1.24	($0.80)
Salt Lake City	Utah Transit Authority	$0.25	$0.51	($0.27)
San Diego	San Diego Metropolitan Transit System	$0.12	$0.50	($0.38)
San Francisco	San Francisco Bay Area Rapid Transit District	$0.12	$1.82	($1.70)
San Francisco	San Francisco Municipal Railway	$0.88	$0.98	($0.10)
San Jose	Santa Clara Valley Transportation Authority	$0.86	$1.20	($0.34)
San Juan	Puerto Rico Highway and Transportation Authority	$1.05	$1.40	($0.35)
Washington, DC	Washington Metropolitan Area Transit Authority	$0.18	$0.91	($0.72)

Since bus, commuter rail, and trolley lines serve as feeders for heavy and light rail transit, however, the lower average operating costs of rail may be somewhat misleading. For example, BART relies on multiple bus agencies and the San Francisco light rail, which are 7 to 16 times more expensive on a per-mile basis. Thus, ignoring the interconnectedness of different types of transit in an urban area could generate misleading results. Nevertheless, this paper focuses on light and heavy rail systems, since many of the critics of rail transit assume that buses could provide similar service more cost-effectively.

Unlike the previous three studies, which include the distorting effects of taxation as a simple ratio of total costs, this paper ignores it. There is no reason to expect that most of the taxes spent on transit would not be collected and spent in the absence of transit. If desired, the costs can be increased by 10% to 30% to account for tax distortion.

CONCLUSION

Despite critiques over inefficiency, many rail transit systems offer net benefits to society. Although these benefits are most pronounced in large, dense cities, several smaller cities with light rail service appear to be welfare enhancing from a cost-benefit perspective. On the other hand, there are at least five systems that have costs that exceed any but the most optimistic of benefits assessments. Even ignoring capital costs, high operating costs per passenger mile and low numbers of passengers suggest that rail may not be a cost-effective technology for these areas. While this paper does not definitively estimate the costs and benefits of rail transit, it does provide a simple, back-of-the-envelope range that supports neither the doom and gloom contention that all rail projects are welfare-harming nor the optimistic assertion that all are welfare-improving.

Estimating fare-elasticities and the impacts of removing rail service, however, are not exercises for which the NTD is particularly well-suited. For one, information is needed on individuals travel behavior to better assess how different groups value transit. Two, the analysis requires the establishment of hypothetical counter-factuals. Without BART, would the Bay Area have invested in more highways? What would the impacts have been? How much would increased bus service cost? Three, the external benefits of transit are complex and difficult to measure, even if a counterfactual can be established. The next step in this analysis is to empirically model the consumer and external benefits of several systems using an activity-based transportation and land use model. Ideally, analyzing the benefits of welfare-improving systems and poorly performing systems will provide insight in the variation in the external benefits of transit and mechanisms for improving rail transit performance more generally.

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