Photo: anouchka/iStock

Chris Severen is a senior economist at the Federal Reserve Bank of Philadelphia. The views expressed in this article are not necessarily those of the Federal Reserve.

A Ticket to Ride

Estimating the Benefits of Rail Transit

Starting in 1990, Los Angeles County built a new and expensive rail transit system. Now we can calculate the costs and benefits.

BY CHRIS SEVEREN

Transportation infrastructure shapes the spatial fabric through which we thread our daily travel. How do we get to work or to school? Where do we go shopping? How long does it take to meet up with friends? Is it worth driving or taking rideshare? Public transit systems–including buses, streetcars, rail lines, and ferries–play a key role in determining our daily travel patterns. Rail transit (subways, light rail, and regional rail) has traditionally been important in older northeastern cities like New York and Philadelphia. Since the 1970s, though, many other cities in the U.S. have sought to increase the mobility available to their residents by building rail transit infrastructure, too.

Building rail is costly and requires large initial public investment. Do the benefits of rail infrastructure outweigh their high costs in younger, more automobile-oriented cities? This is an open question in the U.S., where many cities are polycentric (they have many employment centers rather than a single urban core) and typically not very dense.[1] These factors limit how easy it is for rail transit to connect home to work and other destinations. It is difficult to cost-effectively serve a disperse population that travels to disperse locations with public transit. Further, rail transit infrastructure tends to be very costly in the U.S.

In this article, I discuss why mobility is important and provide an overview of the different ways economists measure the benefits of transit infrastructure. I then describe my hybrid approach, in which I combine three of these methods to study the value of rail transit in Los Angeles.[2] I conclude by conducting a cost-benefit analysis of the first wave of Los Angeles Metro Rail and interpreting the results of this analysis.

LA METRO RAIL IN 2000

Lines	Stations
4	46

Average Weekday
174,554
Ridership

860,579
Passenger miles

Source: 2000 National Transit Database.

Why Does Mobility Matter?

Mobility allows people to access places. The more mobile they are, the more options they have: They can get to more jobs or schools and choose between more places to shop and find services. Being able to access many different workplaces, consume varied goods, and meet with lots of different people is one of the big advantages of living in a city. (Before the modern era of automobile and rail infrastructure—that is, when everyone walked or traveled by horse—most firms were small and people worked and consumed more locally.[3]) Even our network of friends depends on the transportation network.[4]

Greater mobility allows cities to be larger, enabling the comparative advantage of cities in productivity,[5] and one of the most important components of urban mobility is commuting: how workers get to their jobs. Cities let workers connect with a variety of jobs, and firms with a variety of workers. Diverse, productive labor markets make cities the engines of economic growth.[6]

Commuting behavior depends on available transportation infrastructure. Indeed, much transportation infrastructure is designed with peak commuting capacity in mind. (Commuting is, after all, an everyday activity essential to the function of urban economies.) People and firms benefit when this transportation infrastructure makes commuting easier. As an extreme example, in their 2015 paper Ferdinando Monte and his coauthors calculated that prohibiting commuting across county lines would decrease aggregate welfare by 7.2 percent, and the effect in central cities (like Manhattan) would be even greater. Better transportation infrastructure can directly increase employment growth. In their 2012 paper, Duranton and Turner showed that cities with more highways in 1983 gained substantially more employment by 2003 than cities with fewer highways.[7] And transportation infrastructure can address (or exacerbate) certain inequalities. For example, long and challenging commutes may affect women more than men: Women tend to work less in cities with very high congestion and long commutes (like New York City) than in cities where commuting is relatively easy (like Minneapolis).[8]

Transit is valuable also because it enables mobility without automobiles. Some people, because of age, disability, or preference, are unable to drive automobiles.[9] Automobiles can be very costly; households with automobiles on average spend 4.3 times as much on transportation as households that do not use automobiles.[10] There are other consequences of automobile use: They are land- and energy-intensive. The average energy cost for automobiles is about 3,180 British thermal units (BTUs) per passenger mile, while urban subways and light rail use only 24 percent of that energy per passenger mile.[11] Moreover, cities with subways tend to be denser, so the average trip distance is shorter.[12] Because cities that rely on the automobile tend to contain more low-density development, they have a higher carbon footprint.[13] Finally, automobile use can lead to severe congestion in cities, causing substantial delays and decreasing mobility in some settings (Figure 1).

How to Quantify the Benefits of Transit

Economists use several methods to evaluate the benefits of transportation infrastructures, and rail transit in particular. Each method has both advantages and disadvantages.

Hedonics

The hedonic approach compares real estate prices near and far from rail. The intuition is that if (identical) people value transit, they are willing to pay more to live near sites of transit access (like subway stations). This increases the demand for residences near transit stations, which then increases the price of nearby housing. This is particularly true if the supply of housing is relatively fixed, and if transit connects people to where they want to go.

In practice, there are several challenges to simply comparing home prices next to and far from transit. Houses or neighborhoods near transit are often substantially different from those further away; they may be older (or newer), denser, or surrounded by a different set of urban amenities (such as restaurants and schools). Real estate prices also reflect expectations

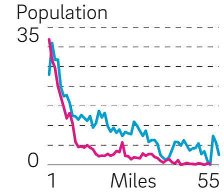
Transportation Spending for Automobile-Owning Households
×4.3
compared to nonowning households

Energy Cost of Automobiles
3,180
BTUs per passenger mile

Energy Cost of Urban Subways and Light Rail
763
BTUs per passenger mile

Density Decreases from Downtown
'000 people/mi² vs. miles from city hall, 2010

Philadelphia vs Los Angeles

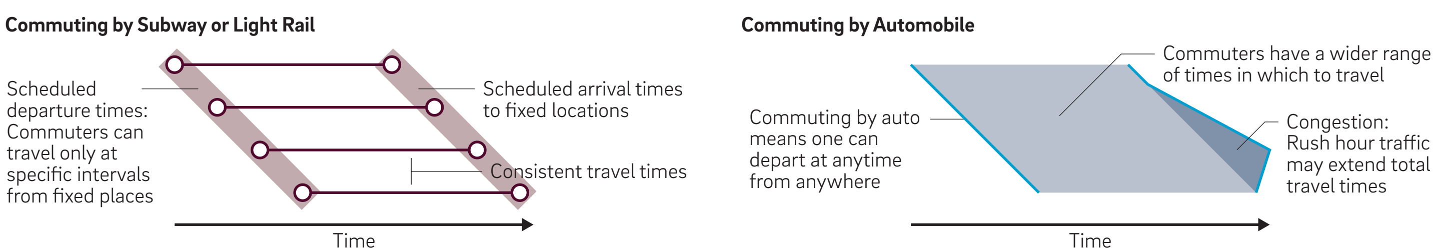


Source: U.S. Census.

FIGURE 1

Commuting Modes Compared

Autos' flexible departure times come at the price of congestion.



about future change. This muddies the interpretation of price gradients near transit. If prices increase in expectation of a transit station opening (that is, before it opens), it could simply be that people expect increases in (nontransit) amenities nearby. So the belief that transit will generate value can make it appear that transit is valued.

It can also be hard to separate the different effects of transit from real estate prices. There may be a mobility benefit that people value, but some real estate price appreciation might instead be due to related transit-oriented development, as new and potentially valuable amenities (such as restaurants and stores) move into an area. Or there could be offsetting negative effects of transit due to the possibility of noise, pollution, or crime.[14] At-grade transportation infrastructure can even serve as a barrier separating neighborhoods from other nearby locations.[15] Careful research design can overcome some of these challenges.[16]

A final challenge with the hedonic approach is that it can be difficult to study demand linkages across space. If people demand more housing near transit and prices rise, these higher prices might cause some people to move to other slightly more distant areas, increasing housing demand and prices in those neighborhoods. The hedonic approach typically compares places with and without transit, and so it misclassifies places without transit as unaffected even if they are indirectly affected by transit.

Modal Choice

Another method compares the relative proportions of people who use different commuting modes to get between similar locations. (Automobile, bus, rail, and walking are all different modes.) By comparing the characteristics (like travel time, average delays, and cost) of the trips that take place on each mode, researchers can calculate how much commuters value these characteristics. For some trips (or along some routes), transit is faster, while for others cars are faster. Comparing these characteristics and the number of people who choose each mode tells us how much people value fast travel, or how much benefit they receive from different trip characteristics. For example, many people value listening to the radio while driving, or reading the paper (or checking Instagram) while riding the train or subway more than they value the speed of either option.

An advantage of this approach is that it can be implemented with a survey, so you can simply ask people about the characteristics of the choices they face and perhaps even the reasons for the choices they make. One challenge with this approach is that researchers must typically assume that they have described all the factors that underlie people's decisions on how to commute. In practice, this can be hard. Many transit modes have highly variable travel times or require waiting for long periods. Both are factors that people particularly dislike, yet both are often ignored.

City Structure

A key tradeoff that drives city structure (and where households and firms choose to locate) is access versus price. Transportation infrastructure allows people better access to inexpensive land. Rail transit does this in a different way than roads, concentrating the benefits of access near transit stations.

People's choices about where to live and work reveal that access is valuable. Aggregating the commuting behavior of people who live in a neighborhood or work in a particular area yields an interesting (though perhaps obvious) conclusion: On average, closer locations have more commuting between them. Economists call this phenomenon gravity, and they have started building spatially explicit models that incorporate this behavior in powerful ways. By combining the notion of gravity with modal choice and transportation data, researchers can estimate the value of increased ease of travel due to transportation infrastructure.[17]

This approach enables researchers to build relatively complex economic models that capture many significant features of urban economies. Moreover, these models typically capture how people move in response to changes in local neighborhoods or commutes. The fact that people move links the demand for housing across space, and can cause local housing prices to reflect changes in other neighborhoods. If this occurs, the hedonic approach will not correctly value these local characteristics, but these more complex models will.

However, this literature has typically assumed that transportation infrastructure only shifts travel outcomes, ignoring other effects it may have. As discussed above, transportation infrastructure can potentially change the quality of residential amenities in a neighborhood or come packaged with zoning policies that increase (or decrease) housing supply. Another challenge facing this literature is that it usually requires a big shock to a city to estimate the models. For example, in their 2015 paper Gabriel Ahlfeldt and his coauthors used the division and reunification of Berlin to estimate their model. It can be challenging to study less extreme settings.

A Combined Approach

Given the different strengths of each of these approaches, there is value in combining them. In my 2019 working paper, I bring together components of these three methods to calculate the total benefits of rail transit. I use spatial data on commuting behavior to directly estimate the commuting effect of transit. I then combine this with hedonic-type estimates of the residential and workplace effects. Finally, I put this all into a model to account for other spillovers across space (Figure 2). The total effect can be decomposed as follows:

Total Effect = (Commuting Effect + Residential Neighborhood Effect + Work Neighborhood Effect) − General Equilibrium Adjustments

I study rail transit in the greater Los Angeles area (Los Angeles and adjacent counties), which has some features that make it particularly valuable as a research subject.

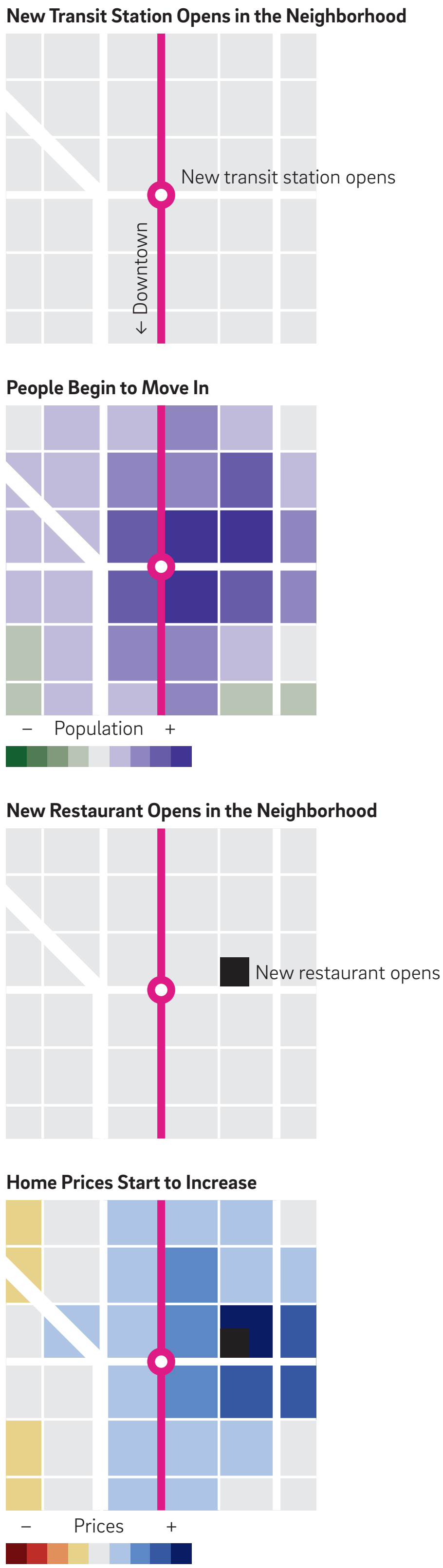
Transit in Los Angeles

The case of Los Angeles offers a number of useful features to evaluate transit. First, greater Los Angeles had no subway or light-rail transit at the beginning of 1990, and it built a relatively

FIGURE 2

Decomposing the Total Effect

There are intermediate steps between the opening of a transit station and an increase in ridership.



large system within 10 years.[18] By 2000, Los Angeles Metro Rail consisted of 46 stations on four lines.[19] This means that it is possible to compare the detailed geography of commuting in Los Angeles before and after rail transit was available. The relatively large system size matters, too. For statistical reasons, it is harder to detect incremental changes if a city adds a few stations (or one line) every decade. Furthermore, there are network effects to transit–the more stations there are (or places that are connected), the more useful the system is and the bigger the benefit.[20]

There's another reason to study Los Angeles Metro Rail. It's relevant for the many automobile-oriented cities considering new subway or light-rail systems. Los Angeles has historically been a poster child for the automobile. It faces many of the transportation issues common to cities that came of age during the automobile era.

Commuting and Noncommuting Effects

To measure the commuting effects of Los Angeles Metro Rail, I use Census Transportation Planning Project data on the number of people who commute from each residential neighborhood to each workplace. I define a neighborhood as a census tract, a unit of measurement used by the Census Bureau.[21] I use data for two years, 1990 and 2000, so that I can look at changes in how many people commute between two tracts. This helps limit the confounding effects of other long-run differences between neighborhoods (or pairs of neighborhoods). I compare the changes in commuting flows between pairs of tracts where both received transit stations and pairs of tracts where at least one did not.

Figure 3 describes the comparisons I make. Transit stations are built in both location A and location B. This means that both of the (directed) pairs AB and BA receive transit. Locations C and D do not receive transit. In total, 10 different pairs do not receive transit: AC, AD, BC, BD, CA, CB, CD, DA, DB, and DC. I compare the average changes in the two pairs that receive transit with the 10 pairs that do not. Better yet, I can also purge the changes at locations A and B that might be caused by the transit station (as well as any other changes that affect only A or B–or C or D, for that matter).[22] This isolates the commuting effect, because the commuting flow between connected locations is the only margin being shifted.

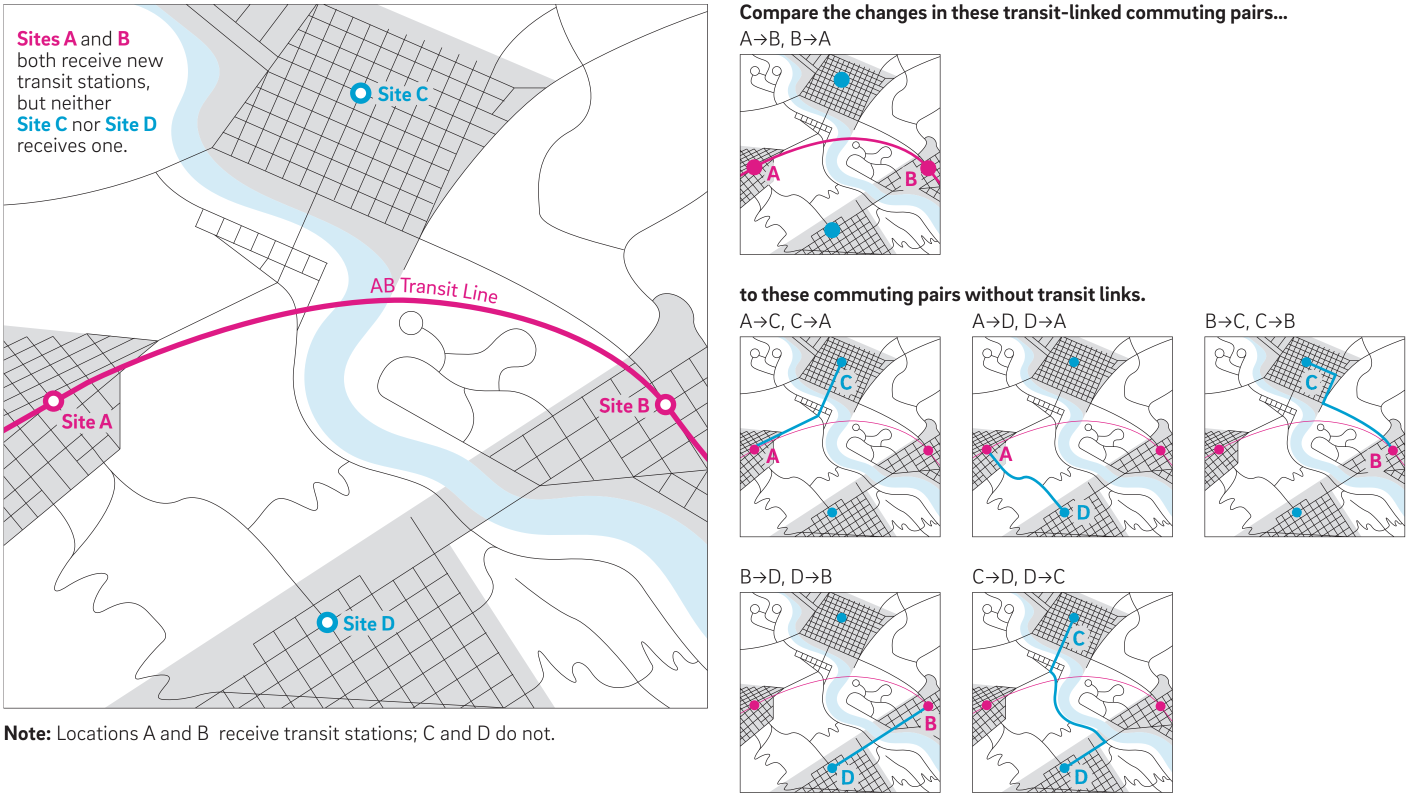
Still, one might worry that these places were connected specifically because planners believed they were most in need of transit connections. If that were so (and if the planners were right), then changes between newly linked neighborhoods might have happened anyway. I limit the control group of neighborhoods (that is, the tracts that did not receive transit linkages) in a couple of different ways to ensure that this is not the case. Both approaches rely on the historical antecedents of Los Angeles Metro Rail to select control neighborhoods that are similar to the neighborhoods that received transit linkages. One approach identifies plausible locations for receiving rail by examining streetcar and interurban rail lines present in the 1920s.[23] Subway and light-rail lines often follow these rights of way, and they tend to align to allow lines to connect. The other comparison uses a historical subway plan from 1925. This plan is more extensive than the subway that was built and so shows many likely routes. Importantly, these routes would have connected historic employment centers and so are less likely to reflect current factors influencing travel demand.

I find strong evidence of a substantial impact of Los Angeles Metro Rail on commuting behavior. Pairs of neighborhoods connected by rail (that is, tracts that both contain stations) experienced a 15 percent increase in commuting between them. Pairs of neighborhoods immediately adjacent to (but not containing) stations saw a 10 percent increase in commuting. More distant places did not see a change (Figure 4). The effect is strongest for pairs of tracts connected by the same subway or light-rail line. (People do not like changing trains, especially when driving is the alternative.) Being close to a station is more important for the workplace location; people seem more willing to walk a moderate distance from home to a station than to walk the same distance from a station to work. Results are consistent across

FIGURE 3

Comparing Effects of Transit Stations

By measuring the commuting flow between connected locations, this model isolates the commuting effect.



Note: Locations A and B receive transit stations; C and D do not.

different comparisons, adding strength to their interpretation as a causal effect.

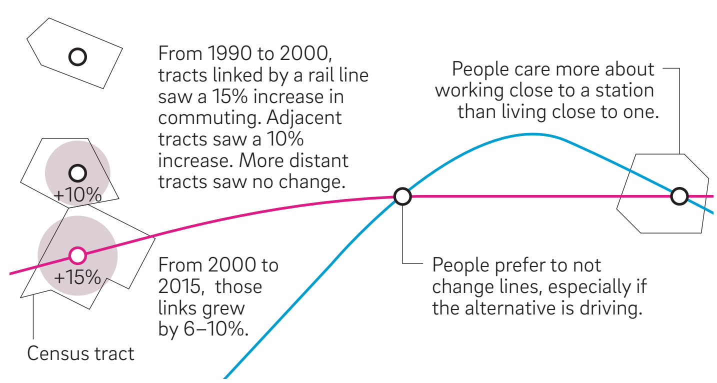
Although my main analysis focuses on the period between 1990 and 2000 (because the data in this period are of the highest quality), commuting may have continued to adjust after the year 2000 in response to the transit linkages built before 2000 that I study. I test for this, and find that commuting between these locations continued to grow relative to other unconnected neighborhoods by 6 to 11 percent over the next 15 years. This delayed effect could be due to slow habituation: It takes people and the built environment a while to adjust to the new transit option. Alternatively, it could be due to the further growth of the Los Angeles Metro Rail network after 2000.[24] People value transit more (and use it more) if it connects them to more places.

There is also evidence of a small reduction in automobile congestion in areas served by rail transit. I compare changes in travel times between pairs of neighborhoods that both lie near a transit station or line with those that do not. Pairs of neighborhoods both within 2 kilometers of a transit line saw a 3 percent reduction in travel time in the long run (though this finding is not the most robust).[25]

Although I find evidence of commuting effects, I find little evidence of noncommuting effects. Residential locations did not, on average, become nicer or worse off because of transit, and workplaces did not become significantly more productive because of transit. These results rely on comparisons between a neighborhood that received a transit station and a neighborhood

FIGURE 4

The Impact of Los Angeles Metro Rail



Source: Author's calculations from Census Transportation Planning Project (CTPP) data.

that did not (rather than comparing a pair of neighborhoods that received a transit linkage to a pair that did not), and so depend more on identifying the correct control group for the comparisons. Nonetheless, there is little evidence of an effect, even when just comparing the neighborhoods most likely to receive transit (as picked out by historic streetcar locations and the 1925 subway plan).[26]

There is also little evidence of a barrier effect. Many transportation projects separate neighborhoods that lie along either side of their routes, driving down the connections to nearby locations.[27] However, the first Los Angeles Metro Rail lines were typically built along existing rail lines, underground, or in highway medians, and so they had little effect.

How Valuable Are These Commuting Effects?

To quantify the monetary value of these effects, I measure how responsive people are to, first, the wages they receive in where they choose to work and, second, the home prices they pay in where they choose to live. The intuition works like this: If a 10 percent increase in wages induces 18 percent more people to work in a location (holding other workplace characteristics constant), then an 18 percent increase in commuting to a location is equivalent to a 10 percent increase in wages.[28] In fact, this 18 percent value is what comes out of the analysis.

The hard part is ensuring that other changes in the workplace or residential neighborhoods do not confound this measurement. For example, if residential housing prices decline because local school quality declines, the local residential population may decrease. Or if employment at the ports goes down because of less shipping due to trade conflicts, the remaining workers could keep receiving the same wage. If I could not account for these other factors, I might conclude that people like higher housing prices and do not care about how much money they make.

Instead of directly trying to account for all the potential factors that could influence these relationships, I try to find something that affects local wages but does not depend on other local factors. I first calculate changes in how productive an industry is, using wages and employment at the national level. I then calculate how much these changes impact each workplace neighborhood based on how much employment in that neighborhood was in each industry in 1990.[29] Overcoming this challenge is a key part of my 2019 working paper, and it (or a similar parameter) is key to translating observed changes to a dollar equivalent in any modal choice or city structure approach.

General Equilibrium Effects

The final component of the analysis is to provide a way to account for spillovers across space. Changes in one neighborhood can affect home prices in other neighborhoods throughout the city because those changes can prompt all households to reevaluate where they want to live, potentially leading some households to move between neighborhoods. This type of general equilibrium effect is important to consider whenever there are large changes to a local economy.

I lightly modify the flexible model of consumer location choice used by Ahlfeldt and his coauthors and apply it to the Los Angeles setting (using the various estimates discussed above). The primary agents in the model are households, who must decide both where to live and where to work. When deciding where to live, they consider residential housing prices and how desirable the neighborhood is. When deciding where to work, they look at what the wages are and how desirable the workplace is. Finally, they also care about how hard it is to travel between a pair of residential and workplace locations.

When transit enters and changes how nice a commute is, or when the characteristics of a neighborhood change, people move. The model makes predictions about the average behavior of people (that is, it tells us where the new population lives but not necessarily who moves where), and so accounts for spillovers in location choice.[30] Housing prices and wages then adjust in response to these changes in where people want to live and work.

Cost-Benefit Comparison and Speculation

Now all the pieces are in place. The commuting effects are measured, there do not appear to be other workplace or residential effects, we have a way to translate these effects into a money-equivalent amount, and we can account for general equilibrium effects.

Combining these pieces, I estimate a benefit of between $109 million and $146 million annually by the year 2000. (The range accounts for whether or not I include the benefits of reduced congestion.) If I include the additional growth in commuting from 2002 to 2015 between locations connected before 2000, the total rises to an upper bound of $216 million annually by 2015.[31] These are purely commuting benefits; they do not account for other travel benefits (such as easing travel for noncommuting trips) or environmental benefits. While these other benefits might be substantial, rail transit is often promoted and judged based on its effect on commuting.[32]

The total cost of the Los Angeles Metro Rail system built by 2000 was $8.7 billion.[33] This can be converted to an annual cost equivalent of between $218 million and $635 million per year.[34] Annual operating subsidies were about $162 million. (These are operating expenses less fare revenue for heavy and light rail.) By summing these numbers, I find that the total annual equivalent cost of Los Angeles Metro Rail as of 2000 was between $380 million and $797 million per year.

The high-end estimates for benefits are therefore about $216 million annually, while the lower end of the costs are at least $380 million annually (Figure 5). This means that there is a sizable discrepancy between the cost of the system and the benefits it delivers even after 25 years.

Why is this the case, and how generalizable is this conclusion? There are two items to consider: How could the benefits have been higher, and how could the costs have been lower.

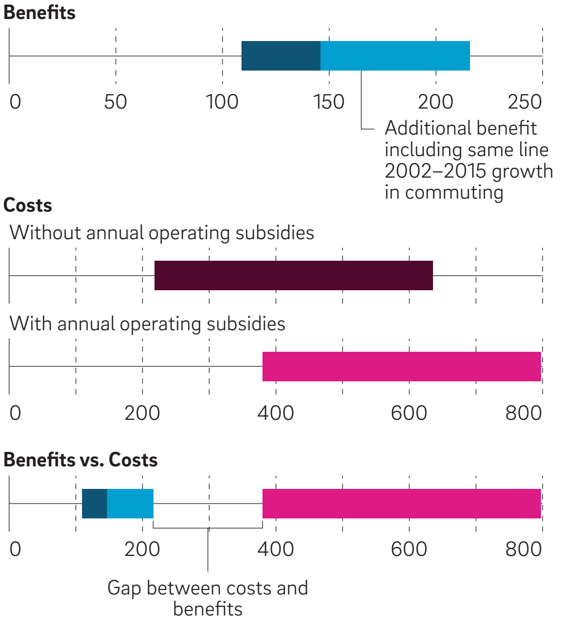
Some of the features that make Los Angeles useful to study mean that a suboptimal system was built. Instead of connecting the densest residential and workplace populations, the subway and light-rail system initially connected many areas between

FIGURE 5

Costs and Benefits of Los Angeles Metro Rail

Despite growth in commuting, there's a sizable discrepancy between costs and benefits.

Range, millions of dollars



Source: Author's calculations based on CTPP; cost numbers from Los Angeles Metro's Adopted Budgets and the U.S. Department of Transportation's National Transit Database.

which there was not a lot of commuting. Restrictive land-use regulations have likely inhibited further development along these rail lines. At the same time, many features of Los Angeles (a polycentric, automobile-oriented city without many high-density areas) are common to other cities building rail transit.

Rail transit construction is generally expensive, and some factors make Los Angeles particularly expensive to build in: Earthquake risk, coastal flooding, and challenging geography all increase costs. What's more, it appears that rail infrastructure typically costs more in the U.S. than in other places.[35] The understanding of why costs are high is still limited. Unfortunately, transit planners are often forced to cut costs by building transit in places where people do not really want to travel, creating a downward spiral in usefulness.

By ridership numbers alone, Los Angeles Metro Rail is actually performing better than the rail transit systems of many other similar cities. In building a relatively large network that begins to cover a geographically large cosmopolis, Los Angeles Metro Rail could serve as the basis of a large transit system integral to mobility in Los Angeles 100 years from now. New York City in 2004 was much larger and denser than it was in 1904, when its first subway line was completed. However, planners and politicians rarely get the latitude or budget to plan on such timescales.

Notes

1 See Anas, Arnott, and Small (1998).

2 See Severen (2019) for details of this hybrid method.

3 See Heblich, Redding, and Sturm (2018) and You (2017).

4 See Bailey et al. (2019).

5 Economists call the general phenomenon of increased productivity in or near large collections of people or firms agglomeration. See Chatman and Noland (2014).

6 See Duranton and Puga (2004) and Rosenthal and Strange (2004).

7 On average, and across cities worldwide, subways appear to have an insignificant impact on overall population growth, though they lead to more concentrated cities than does comparable highway construction. See Gonzalez-Navarro and Turner (2018).

8 See Black, Kolesnikova, and Taylor (2014).

9 Of course, automobiles are also valuable for increasing the mobility of some people with disabilities.

10 See Department of Transportation (2018).

11 See Davis, Williams, and Boundy (2016).

12 See Duranton and Turner (2018).

13 See Mangum (2017).

14 See Bowes and Ihlanfeldt (2001).

15 See Brinkman and Lin (2019).

16 See, for example, Billings (2011) and Chen and Whalley (2012).

17 See, for example, Allen and Arkolakis (2019) and Tsivanidis (2018).

18 Spatially detailed data on commuting behavior is available only for 1990 and 2000, and since 2002.

19 It was operated as three lines at the time; one line had two branches. These are now operated as two lines.

20 There were also unique factors that arose during the planning and construction of Los Angeles Metro Rail that help clearly differentiate the direct effects of Los Angeles Metro Rail from other factors that could influence neighborhood change. These factors argue for interpreting the estimates described below as causal (rather than simply correlative). See Severen (2019) for a description of an exploding clothing store and more discussion.

21 Census tracts have on average 4,000 residents, though size can vary quite a bit. There are about 2,400 census tracts in the area under study, implying approximately $2{,}400^2$=5.76 million pairs of residential-workplace connections.

22 This is accomplished by using neighborhood-by-year fixed effects.

23 Red Cars (the Pacific Electric Railroad's Los Angeles streetcar system) were a notable component of commuting in Los Angeles prior to WWII. The last Red Car ran in 1961.

24 Neighborhoods that first became connected between 2002 and 2015 experienced a 9 to 13 percent increase.

25 This is between one-third and one-quarter the size of the short-run effect Anderson found in his 2014 paper. He used the Los Angeles Metro Rail labor strike of 2003 to provide very high-quality evidence that the presence of rail service reduced congestion (as measured by vehicle speed) along Los Angeles freeways by up to 12 percent. The difference in findings is most likely due to the time frame: I study changes in congestion after years have passed, while Anderson focused on travel during an event that lasted about five weeks.

26 Because of data limitations, I only studied noncommuting outcomes between 1990 and 2000 (rather than extending the analysis to 2015, as I do for commuting).

27 See Brinkman and Lin (2019).

28 A similar approach works with housing prices, with one small adjustment: We must account for the fact that people spend only part (typically about one-third) of their income on housing. So if a 10 percent reduction in housing prices in a neighborhood (holding other characteristics of the neighborhood constant) induces 18% × (⅓) = 6% more people to live in a neighborhood, then a 6 percent increase in commuting from that location is equivalent to a 10 percent reduction in housing prices.

29 Economists call these variables shift-share or Bartik instrumental variables. Because of the particular setting and data in my 2019 working paper, many critiques of this approach are not relevant here.

30 Economists often consider other externalities, sometimes called spillovers, in these models. A typical externality is agglomeration. Though I discuss this in my working paper, I do not discuss it here.

31 The increased commuting between 2002 and 2015 could be attributed to either the slow adjustment of people to Los Angeles Metro Rail or the growth of the network and increased service area after 2002. The $216 million annual benefit attributes all the growth to slow adjustment (and can therefore use the same cost basis as the $109–$146 million annual benefit estimate).

32 For example, Nicolas Gendron-Carrier and his coauthors found that subways decrease air pollution. Applying their estimates and methods to Los Angeles suggests that Los Angeles Metro Rail may have up to an additional $180 million in annual benefits (roughly equal to the commuting benefit). Accounting for this brings total benefits within the lower end of the cost range. However, it is not obvious that these benefits represent a long-run gain, as decreased congestion from rail transit could eventually induce more driving (and thus more pollution).

33 All dollar amounts have been inflation-adjusted to their 2015 equivalents. Figures are author's calculations based on LACMTA fiscal year budget filing reports.

34 The range captures the wide variety of assumptions used to value the benefits of infrastructure projects.

35 There exists little detailed work comparing costs internationally, but Alon Levy has created perhaps the most exhaustive dataset at his blog, Pedestrian Observations. Brooks and Liscow (2019) showed that the costs of other transportation infrastructure in the U.S. (specifically, highways) started to increase substantially in the late 1970s.

References

Ahlfeldt, Gabriel M., Stephen J. Redding, Daniel M. Sturm, and Nikolaus Wolf. "The Economics of Density: Evidence from the Berlin Wall," *Econometrica*, 83:6 (2015), pp. 2127–2189, https://doi.org/10.3982/ECTA10876.

Allen, Treb, and Costas Arkolakis. "The Welfare Effects of Transportation Infrastructure Improvements," NBER Working Paper w25487 (2019), https://doi.org/10.3386/w25487.

Anas, Alex, Richard Arnott, and Kenneth A. Small. "Urban Spatial Structure," *Journal of Economic Literature*, 36:3 (1998), pp. 1426–1464.

Anderson, Michael L. "Subways, Strikes, and Slowdowns: The Impacts of Public Transit on Traffic Congestion," *American Economic Review*, 104:9 (2014), pp. 2763–2796, https://doi.org/10.1257/aer.104.9.2763.

Bailey, Michael, Patrick Farrell, Theresa Kuchler, and Johannes Stroebel. "Social Connectedness in Urban Areas," NBER Working Paper w26029 (2019).

Billings, Stephen B. "Estimating the Value of a New Transit Option," *Regional Science and Urban Economics*, 41:6 (2011), pp. 525–536.

Black, Dan A., Natalia Kolesnikova, and Lowell J. Taylor. "Why Do so Few Women Work in New York (and so Many in Minneapolis)? Labor Supply of Married Women Across U.S. Cities," *Journal of Urban Economics*, 79 (2014), pp. 59–71.

Bowes, David R., and Keith R. Ihlanfeldt. "Identifying the Impacts of Rail Transit Stations on Residential Property Values," *Journal of Urban Economics*, 50:1 (2001), pp. 1–25.

Brinkman, Jeffrey C., and Jeffrey Lin. "Freeway Revolts! Highways, Downtown Amenities, and Urban Growth," Federal Reserve Bank of Philadelphia Working paper 19-29 (2019).

Brooks, Leah, and Zachary D. Liscow. "Infrastructure Costs," unpublished manuscript (2019), https://dx.doi.org/10.2139/ssrn.3428675.

Chatman, Daniel G., and Robert B. Noland. "Transit Service, Physical Agglomeration and Productivity in U.S. Metropolitan Areas," *Urban Studies*, 51:5 (2014), pp. 917–937, https://doi.org/10.1177%2F0042098013494426.

Chen, Yihsu, and Alexander Whalley. "Green Infrastructure: The Effects of Urban Rail Transit on Air Quality," *American Economic Journal: Economic Policy*, 4:1 (2012), pp. 58–97, https://doi.org/10.1257/pol.4.1.58.

Davis, Stacy C., Susan E. Williams, and Robert G. Boundy. *Transportation Energy Data Book: Edition 35*, Knoxville, TN: Oak Ridge National Laboratory, 2016.

Department of Transportation, Bureau of Transportation Statistics. "TET 2018—Chapter 6—Household Spending on Transportation." In *Transportation Economic Trends*, 2018, https://www.bts.gov/browse-statistical-products-and-data/transportation-economic-trends/tet-2018-chapter-6-household.

Duranton, Gilles, and Diego Puga. "Micro-foundations of Urban Agglomeration Economies." In J. Vernon Henderson and Jacques-François Thisse, eds., *Handbook of Regional and Urban Economics*, vol. 4, San Diego: Elsevier, 2004, pp. 2063–2117.

Duranton, Gilles, and Matthew A. Turner. "Urban Growth and Transportation," *Review of Economic Studies*, 79:4 (2012), pp. 1407–1440, https://doi.org/10.1093/restud/rds010.

Duranton, Gilles, and Matthew A. Turner. "Urban Form and Driving: Evidence from U.S. Cities," *Journal of Urban Economics*, 108 (2018), pp. 170–191.

Gendron-Carrier, Nicolas, Marco Gonzalez-Navarro, Stefano Polloni, and Matthew A. Turner. "Subways and Urban Air Pollution," NBER Working Paper w24183 (2018).

Gonzalez-Navarro, Marco, and Matthew A. Turner. "Subways and Urban Growth: Evidence from Earth," *Journal of Urban Economics*, 108 (2018): pp. 85–106.

Heblich, Stephan, Stephen J. Redding, and Daniel M. Sturm. "The Making of the Modern Metropolis: Evidence from London," NBER Working Paper w25047 (2018), https://doi.org/10.3386/w25047.

Levy, Alon. Pedestrian Observations: Construction Costs, (2011). https://pedestrianobservations.com/construction-costs/.

Mangum, Kyle. "The Role of Housing in Carbon Emissions," Andrew Young School of Policy Studies Research Paper Series 17-05 (2017), https://dx.doi.org/10.2139/ssrn.2957749.

Monte, Ferdinando, Stephen J. Redding, and Esteban Rossi-Hansberg. "Commuting, Migration, and Local Employment Elasticities," NBER Working Paper w21706 (2015).

Rosenthal, Stuart S., and William C. Strange. "Evidence on the Nature and Sources of Agglomeration Economies." In J. Vernon Henderson and Jacques-François Thisse, eds., *Handbook of Regional and Urban Economics*, vol. 4, San Diego: Elsevier, 2004, pp. 2119–2171.

Severen, Christopher. "Commuting, Labor, and Housing Market Effects of Mass Transportation: Welfare and Identification," Federal Reserve Bank of Philadelphia Working Paper 18-14/R (2019).

Tsivanidis, Nick. "The Aggregate and Distributional Effects of Urban Transit Infrastructure: Evidence from Bogotá's TransMilenio," unpublished manuscript (2018).

You, Wei. "The Economics of Speed: The Electrification of the Streetcar System and the Decline of Mom-and-Pop Stores in Boston, 1885–1905," unpublished manuscript (2017).