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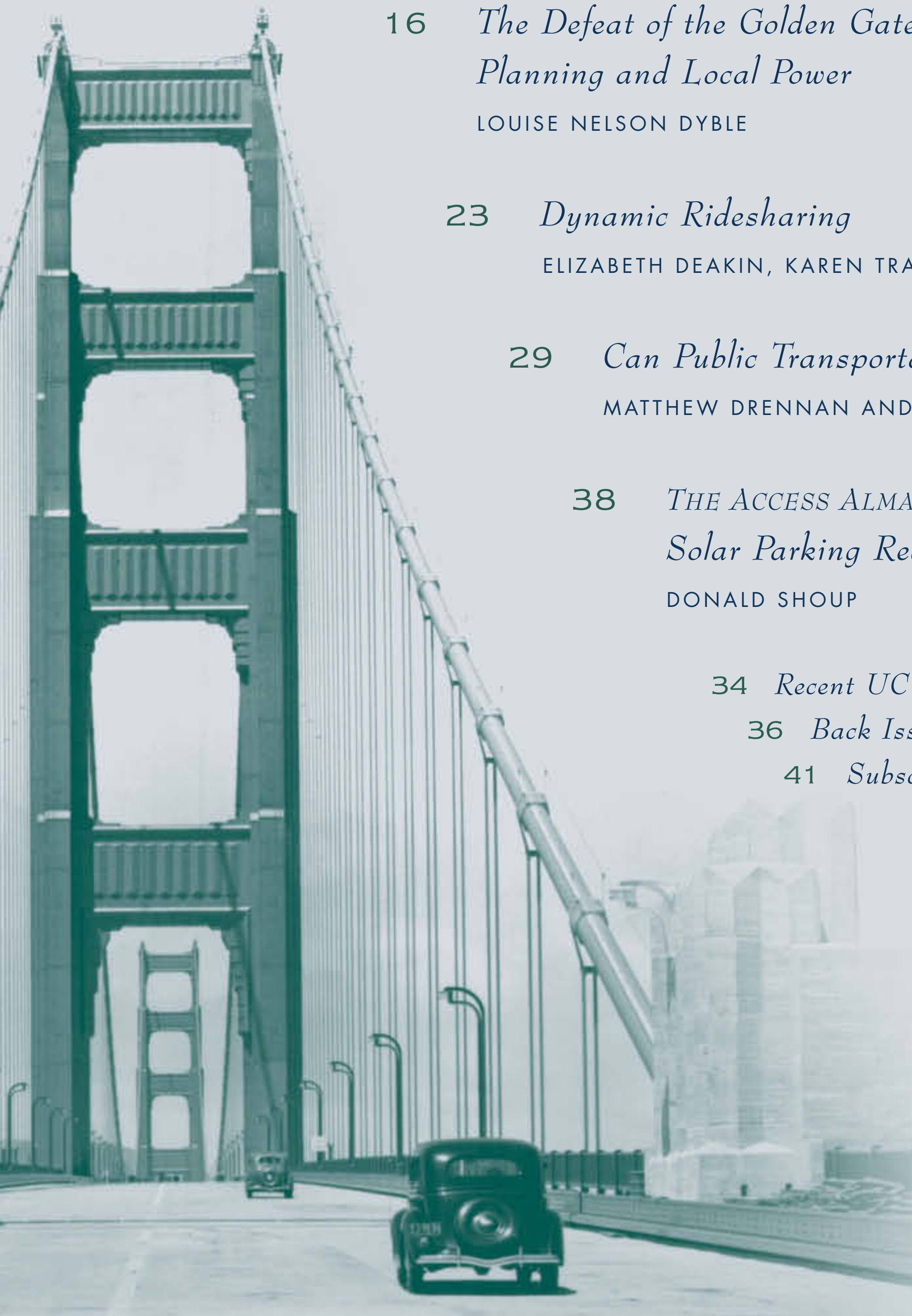

This spring the Golden Gate Bridge celebrates its 75th anniversary.

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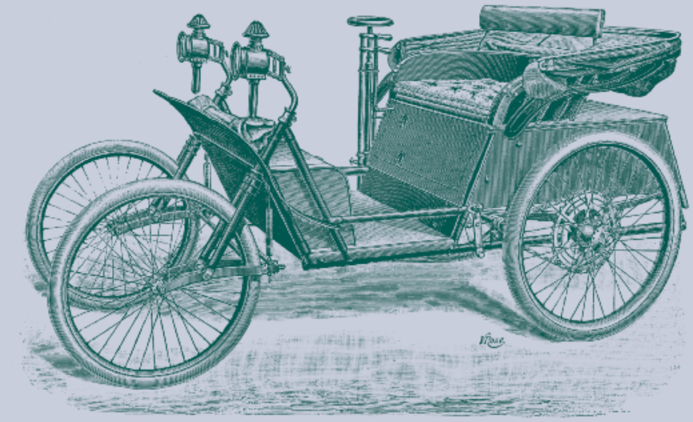

Transit and the "D" Word

ERICK GUERRA AND ROBERT CERVERO

WITHOUT HIGH PATRONAGE, NEW RAIL INVESTMENTS INCUR LARGE DEFICITS and fail to deliver promised environmental and social benefits. A system with few passengers and a high price tag is, by most accounting, a poor investment economically, environmentally, and socially. Comparing the costs and the number of passenger-miles traveled for 54 American rail transit investments since 1970, we found wide variation in cost-effectiveness. The worst-performing system costs nearly 50 times more per passenger-mile than the best-performing. What factors distinguish the most successful transit investments?

Dense concentrations of people and jobs around transit stations are particularly important. Outside of Manhattan, Chicago's Loop, and a few other urban pockets, however, most Americans dislike density. Many loathe it. For them, the "D" word means traffic congestion, crowded sidewalks, packed schools, long lines at the grocery store, and high crime rates. Without density, however, high-capacity transit tends to attract too few trips to offset the high price tag. As a result, there is a great interest in the minimum densities needed to support transit.

We review the literature on transit success and density, establish a methodology for evaluating cost-effectiveness, and relate this back to the numbers of jobs and residents around transit stations. Many recent transit investments have fallen short of the mark. Continuing to invest in high-capacity transit in low-density areas will require large subsidies per passenger trip and produce few tangible benefits. Instead, we recommend prioritizing investments in areas that meet, or have credible plans to meet, minimum density thresholds.

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Transit and Population Density

In 1965, John Meyer, John Kain, and Martin Wohl wrote, "nothing is so conducive to the relative economy of rail transit as high volumes and population density. High population density increases the costs of all urban transportation, but substantially less for rail than for other modes." They and other scholars found that rail transit, with its high up-front investment and high capacity, costs less than buses or cars only in corridors with high travel demand. Thus they found that rail was more cost-effective than buses or cars in high-density cities, while cars were more cost effective in low-density cities. The majority of job and population growth, however, was occurring in newer, low-density cities and in distant suburbs.

A decade later, Boris Pushkarev and Jeffrey Zupan estimated minimum density thresholds for different types of public transit. According to their calculations, net residential densities of 12 households per acre surrounding a 50-million square-foot central business district (CBD)—roughly the size of Los Angeles' or Newark's downtown in 1970—could support a cost-effective heavy-rail investment. Nine households per acre surrounding a 20-to-50 million square-foot CBD could, at that time, support a minimal light-rail investment. By their calculations, Los Angeles, Seattle, and Honolulu could ➢

support heavy-rail transit, while Houston, Detroit, Dallas, Baltimore, and Miami were candidates for more limited, primarily above-grade, investments. Along with coauthor Robert Cumella, Pushkarev and Zupan later recommended light rail, with varying degrees of length and grade separation, for 16 mid-sized cities including Buffalo, Dallas, and Portland. Most of these cities have since built some form of light rail. The authors did not evaluate Sacramento or San Jose, and they recommended a no-build alternative for Phoenix; today all three cities operate light rail.

Given a fixed pot of transit funding, cities should spend it on the projects that provide the highest benefits.

Hindsight has not been 20/20. Pushkarev, Zupan, and Cumella's recommendations are no less controversial today than they were three decades ago. Nevertheless, we can analyze and compare recent investments and investigate the factors—including density—that influence costs and passenger volumes. What levels of density are needed to support rail investments? While critics and advocates will continue to disagree on the merits of individual projects and transit in general, they can probably agree that, given a fixed pot of transit funding, cities should spend it on the projects that provide the highest benefits.

The Investments

We looked at 54 light-rail and heavy-rail investments from 1970 to 2006 in 20 US cities. Together they cost $66 billion in 2008 dollars and include 652 transit stations and 691 route-miles. To include data on fare revenues, operating costs, and passenger trips over time, we matched the investment data to annual system-level transit data. We also considered annual estimates of the number of jobs and residents around transit stations and other factors that influence transit ridership, such as fuel prices and economic growth.

Findings

Wide Variation

Recent transit investments have required large subsidies to cover operating losses and debt financing for capital costs. The net annual cost—operating costs and annualized capital costs minus fare revenues—is an approximation of the total financial subsidy across federal, state, and local agencies each year. The actual annual subsidy depends on other sources of revenue (such as advertising and lease payments) as well as loan terms and other capital finance mechanisms (such as tax-increment financing). In 2008, the median net cost, or subsidy, was $0.93 per passenger-mile, while the average net cost was $1.35 per passenger-mile. The standard deviation of $1.55 was higher than the average.

Several particularly expensive investments drive up the average. Table 1 lists the net annual costs per passenger-mile traveled (PMT) of each of the rail investments. Just over 80 percent had net costs of less than $2.00 per passenger-mile and approximately 20 percent had net costs of less than $0.50. The 2006 Newark light-rail extension from Penn Station to Broad Street required a staggering estimated subsidy of $10.43 per passenger-mile. The best-performing project, the Denver Central Corridor, cost $0.22 per passenger-mile after netting out fare revenues. Of the ten best performing investments, half are light rail and half are heavy rail.

The Cost-per-Mile Metric

More than capital costs, the number of passengers determines which systems are cost-effective. While researchers and journalists often compare rail investments by looking at how much they cost to build per route-mile, the benefits of low capital costs are often offset by even lower ridership. Of the 54 projects we examined, the heavy rail systems cost more than four times per route-mile to build as the light-rail systems, but due to higher patronage, were less expensive per passenger-mile. For example, the first section of the Red Line in Los Angeles cost more to build per route-mile than any other investment but had below average costs per passenger-mile. Because of its low ridership, San Jose light rail had among the highest costs per passenger-mile despite low investment costs per route-mile.

As a metric for comparing transit costs, cost per route-mile is somewhat misleading because the most expensive investments often have many more riders than less expensive ones. That said, the most cost-effective projects in our study had below-average capital costs per route-mile. Even if some of the least capital intensive projects are among the most expensive per passenger-mile, reducing upfront investment costs is an important component of increasing the cost-effectiveness of individual projects.

Unmet Thresholds

Despite an emphasis on escalating costs in transit literature, to our surprise we did not find a clear relationship between the age of an investment and its cost-effectiveness. Despite wide variation, Pushkarev and Zupan's inflation-adjusted estimates of average rail transit capital costs were largely accurate. We did, however, find that the neighborhoods around new rail stations generally did not meet Pushkarev and Zupan's minimum population density thresholds. The *average* rail investment of the past four decades has fewer surrounding households per acre than the authors' recommended *minimum*. ➢

TABLE 1

Average Capital and Operating Costs Net of Fare Revenue per Passenger-Mile Traveled by Rail Investment in 2008

CITY	CORRIDOR	NET COST PER PMT	CITY	CORRIDOR	NET COST PER PMT	CITY	CORRIDOR	NET COST PER PMT
Denver	Central Corridor	$0.22	Washington	Shady Grove (A) Red	$0.72	Portland	Portland Airport Max	$1.21
San Francisco	Initial BART	$0.32	Washington	Yellow Line	$0.73	Baltimore	Three extensions	$1.24
Washington	Anacostia Outer (F)	$0.32	Los Angeles	Long Beach Blue Line	$0.74	Sacramento	Sacramento Folsom Corridor	$1.31
San Diego	Orange Line	$0.42	St. Louis	St. Louis St. Clair County Extension	$0.81	Los Angeles	Red Line (Segment 3)	$1.41
Portland	Portland MAX Segment I	$0.42	Dallas	S&W Oak Cliff and Park Lane	$0.84	Los Angeles	Red Line (Segment 2)	$1.52
San Diego	Blue Line	$0.43	San Diego	Mission Valley East	$0.86	Washington	Addison (G) Blue Line	$1.53
Minneapolis	Hiawatha Corridor	$0.49	Atlanta	North Line Dunwoody Extension	$0.92	Baltimore	Baltimore Metro	$1.66
Washington	Glenmont (B) Red	$0.49	Sacramento	South Phase 1	$0.92	Jersey City	Hudson-Bergen MOS 1 and 2	$1.68
Washington	Vienna (K) Orange	$0.50	Los Angeles	Green Line	$0.92	San Jose	San Jose North Corridor	$2.09
Washington	Franconia/Springfield (J/H) Blue Line	$0.50	San Francisco	BART SFO Extension	$0.95	Denver	Denver Southeast (T-REX)	$2.34
Atlanta	North / South Line	$0.50	Portland	Portland Westside/Hillsboro MAX	$0.97	San Jose	VTA Capitol Segment–Connected to Tasman East	$2.43
Washington	New Carrollton (D) Orange	$0.53	Boston	Southwest Corridor	$1.01	San Jose	VTA Vasona Segment	$2.64
Chicago	O'Hare Extension (Blue Line)	$0.56	Dallas	North Central	$1.02	San Jose	Tasman East	$2.70
Denver	Denver Southwest Corridor	$0.56	Los Angeles	Red Line (Segment 1)	$1.02	Buffalo	Buffalo Metro Rail	$3.47
Sacramento	Mather Field Road Extension	$0.58	Washington	Largo Metrorail Extension	$1.02	Trenton	Southern New Jersey Light Rail Transit System	$3.73
Chicago	Orange Line	$0.60	Portland	Portland Interstate MAX LRT	$1.03	San Jose	Tasman West	$4.71
Sacramento	Sacramento Stage I	$0.68	Baltimore	Central Line	$1.04	Newark	Newark Elizabeth MOS-1	$10.43
Washington	U street (E) Green	$0.71	Miami	Metrorail	$1.05			
			Los Angeles	Pasadena Gold Line	$1.15			

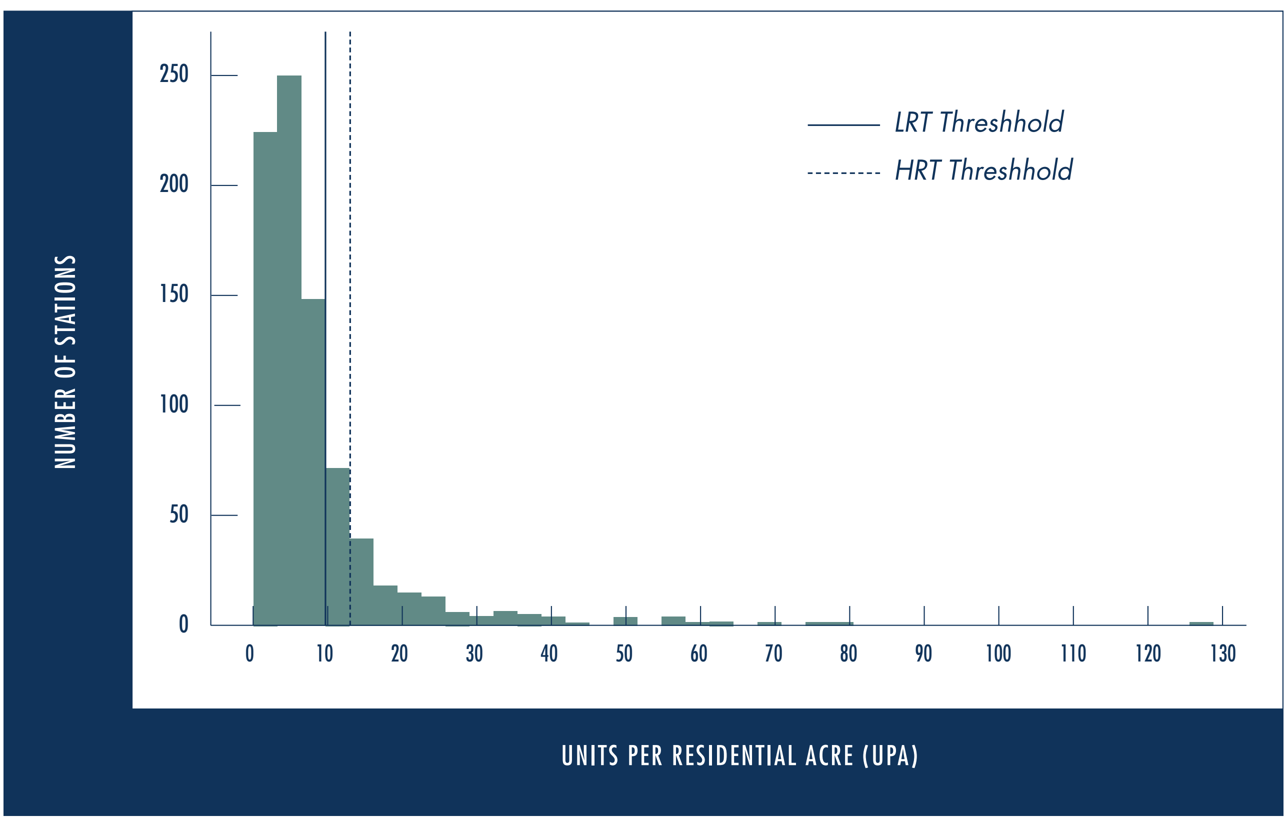
Just 26 percent of heavy-rail station areas and 19 percent of light-rail station areas surpass the minimum recommended thresholds. Figure 1 plots the average gross residential density, in 2000, of 526 light-rail and 261 heavy-rail stations that have opened since 1972 against the thresholds. More than high costs, this absence of density has hindered transit performance due to a shortage of origins and destinations around transit stations.

Updated Cost-Effectiveness Thresholds

Using our recent investment and system data, we calculated minimum land use density thresholds for otherwise-average transit systems to be highly cost-effective. We defined cost-effective investments as investments that increased passenger-miles for a smaller estimated subsidy than either fare reductions or increased train frequencies on existing systems. Fare reductions, less expensive than increased frequencies, required an estimated $0.58 subsidy for each new passenger-mile. Roughly a quarter of the investments met this cutoff (Table 1). They carried 57 percent of passenger-miles on the 54 investments in 2008. Table 2 presents the minimum population density threshold to achieve high cost-effectiveness in an average light-rail and heavy-rail city with 100,000 and 350,000 jobs within a half mile of transit stations in the system. These thresholds assume that all other inputs, such as average fares, transit frequency, number of jobs within a half mile of stations, and track length, remain constant and average. At an investment cost of $25 million per route-mile, an average light-rail system in an average city will tend to be cost-effective with at least 14 people per gross acre living within a half mile of stations.

FIGURE 1

Density (Units per Residential Acre) around Light- and Heavy-Rail Stations Opened since 1972



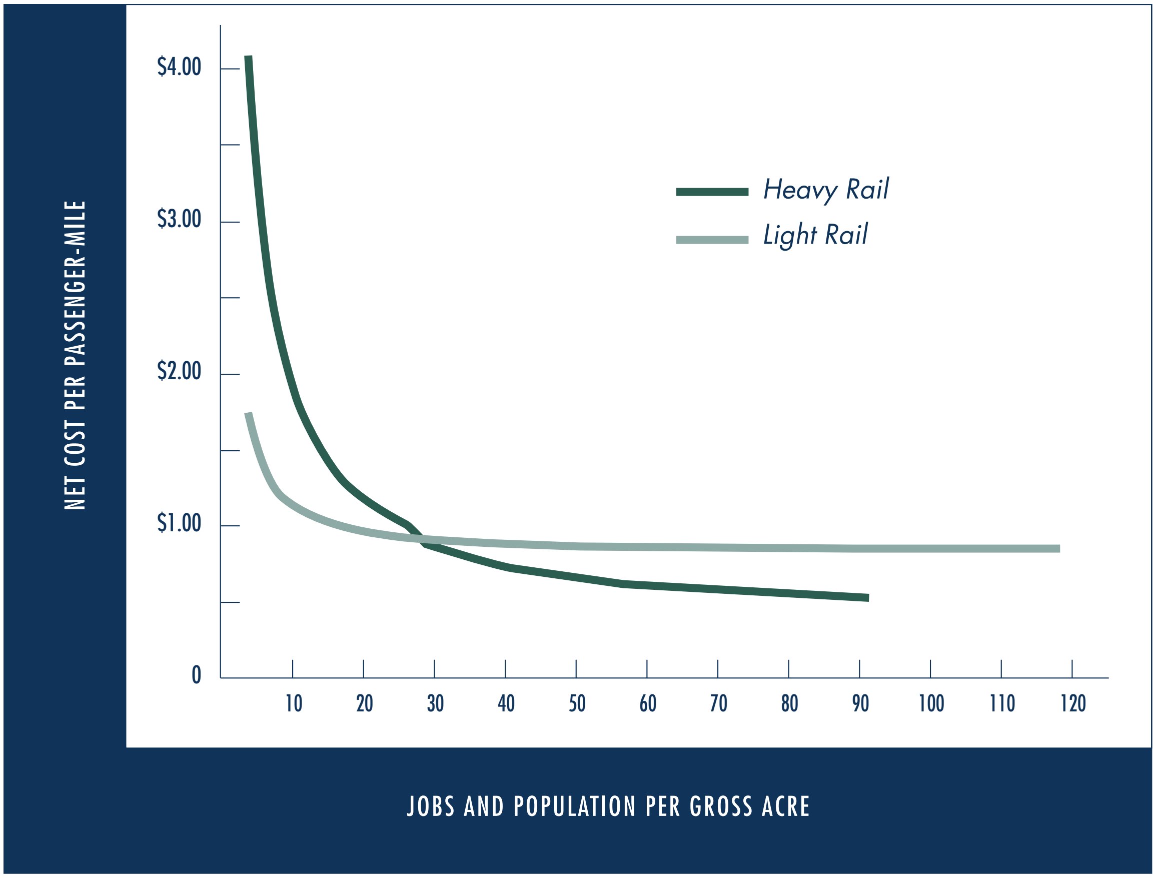


FIGURE 2

Net Cost per Passenger-Mile by Jobs And Population Density in Average Light- and Heavy-Rail Cities

It is more expensive to build rail transit in dense areas, because of higher land-acquisition, labor, and relocation costs. Accordingly, we modeled cost per passenger-mile while allowing capital costs, as well as operating costs and passenger-miles, to vary with changes in job and population density. The results, graphed in Figure 2, suggest that, on average, light rail is more cost-effective than heavy rail in areas of up to approximately 28 residents and jobs per gross acre. With system-area densities near or below 20 residents and jobs per acre, Atlanta, Miami, and Baltimore appear better suited for light than heavy rail, while heavy rail is the appropriate choice in the San Francisco Bay Area and Washington, DC.

Costs and Jobs Matter

Transit-supportive density thresholds need to be viewed with caution. There is no one hard and fast rule that can be applied across all projects. Regression-based models mask considerable variation. For example, despite low surrounding densities, the Franconia-Springfield extension of the Blue Line in Washington, DC, is one of the best performing investments. Low capital costs, a plentiful supply of parking at stations, frequent train service, and good access to downtown jobs contribute to low costs per rider. By contrast, the Buffalo light-rail system is one of the least cost-effective, despite above-average job and population densities.

Furthermore, according to our model, average-cost, average-performance heavy-rail investments need surrounding densities of approximately 45 residents per gross ➢

TABLE 2

Population Density Thresholds for Cost-Effective Transit at a Range of Capital Costs for Otherwise-Average Light- And Heavy-Rail Systems

CITY SIZE	CAPITAL COST PER MILE *(in Millions USD)*	POPULATION PER GROSS ACRE
MEDIUM CITY (LRT) 100,000 Jobs within a Half Mile of Stations	$25	14
	$50	32
	$75	50
	$100	67
LARGE CITY (HR) 350,000 Jobs within a Half Mile of Stations	$100	9
	$150	22
	$200	36
	$250	50
	$500	119

acre within a half mile of stations to meet the cost-effectiveness threshold. Light rail needs about 30 residents per gross acre (Table 2). Only New York has higher average population densities around stations. Given political resistance to residential densification and market realities, city agencies cannot rely on residential density alone to promote cost-effective transit. They also need to increase the number of jobs around transit and to reduce capital and operating costs.

In terms of density, increasing the number of jobs around stations appears to have a stronger impact on ridership than increasing the number of residents. Since jobs tend to be concentrated around existing downtown stations, however, few system expansions are likely to capture significant job concentrations. This means that rail expansions in residential areas need to be coordinated with proactive policies to facilitate job growth in other areas.

Mass Transit Needs Mass

At a time when fiscal resources are shrinking, rail transit has become a lightning rod for political controversy and infighting. Critics consider rail proposals to be among the most flagrant forms of pork-barrel politics today. Advocates counter that aggressively expanding the nation's rail transit systems will, over the long run, yield many under-appreciated environmental and societal benefits, including reduced carbon emissions and reduced dependence on foreign oil. Yet if rail transit is to yield appreciable dividends, there must be a closer correspondence between transit investments and urban development patterns. Many recent investments have failed in this regard.

All too often, rail transit investments in the US have been followed by highway-oriented, rather than transit-oriented, growth. Many systems lack the job or population concentrations that support cost-effective transit service. Despite the unease many citizens, planners and politicians have with density, if costly rail and BRT investments are to pay off, larger shares of growth—particularly jobs—must be concentrated around transit stops. In addition to local land use policies, this will require a significant reorientation of transit funding priorities in favor of investments in areas that meet, or have credible plans to meet, minimum density thresholds. ◆

FURTHER READING

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Thinking Outside the Bus

HIROYUKI ISEKI, MICHAEL SMART,
BRIAN D. TAYLOR, AND ALLISON YOH

IN AN ERA OF STRETCHED TAX REVENUES, SHRINKING PUBLIC SECTOR BUDGETS, and partisan debates over the appropriate role and scale of government, investments in public transit systems have been increasing. While the Great Recession has recently squeezed many transit operating budgets, overall public capital and operating subsidies of transit systems have grown dramatically over the past decade. Why have transit expenditures grown when so many other facets of public expenditure have shrunk? Concerned with chronic traffic congestion, sprawl, and the environmental sustainability of car-centered transportation, officials at all levels of government have shifted urban transportation priorities from increasing road capacity to increasing transit capacity, especially in the biggest metropolitan areas. We have, in other words, bet heavily on public transit to help us solve pressing social and environmental problems. ➢

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While transit ridership is up, transit subsidies have risen far faster.

So is our bet paying off? The good news is that national transit patronage in 2009 was up 36 percent over 1995, and up 9 percent over 2001. The rate of growth for transit ridership has outpaced metropolitan population, which has grown 16 percent since 1995 and 7.5 percent since 2001. But transit *service* has grown much faster than transit *use*. Since 2001, vehicle-hours of transit service rose by 23 percent, but transit passengers per vehicle-hour declined by 11 percent. Given these countervailing trends, it is no surprise that public transit subsidies—the tax dollars required to cover the gap between the cost of providing transit service and farebox revenues—increased by 66 percent between 1995 and 2009, after controlling for the effects of inflation. So while transit use is up, transit subsidies have risen far faster—meaning that the effectiveness of these subsidies is dropping at an alarming rate.

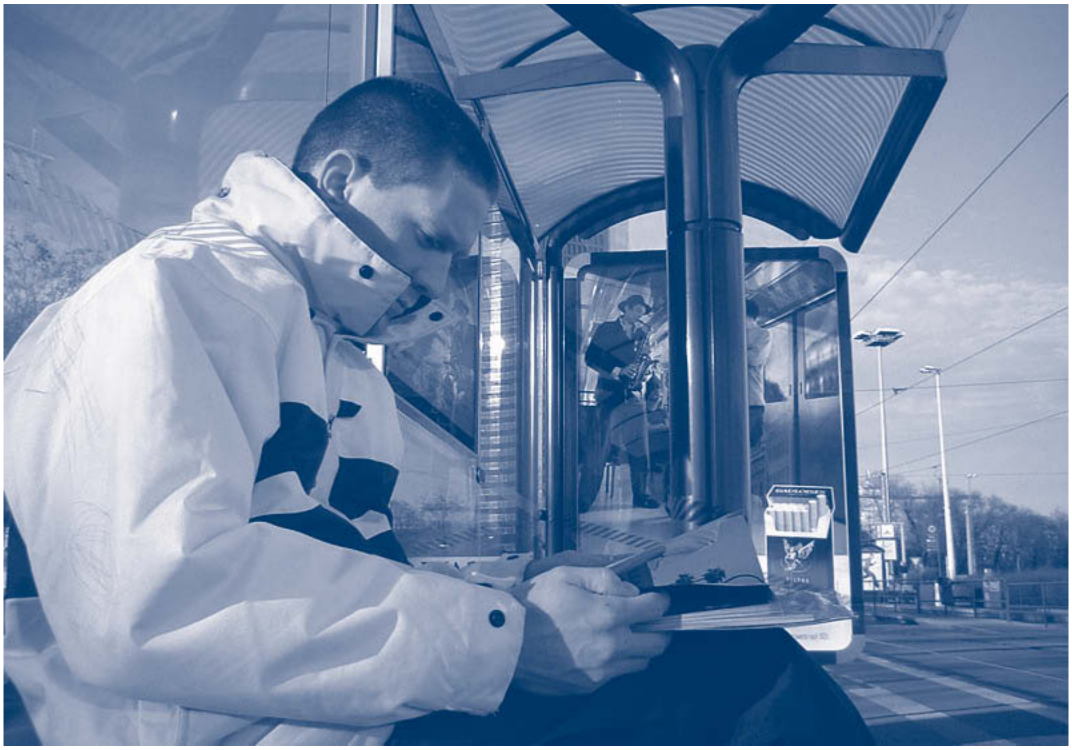
Why are increasing transit subsidies "buying" so few new riders? This simple question has a complicated answer. One important part of the answer has been the focus on investing in new high-capacity, trunk-line services in relatively few corridors, which often feature elaborate stops and stations intended to serve as magnets for development. Sleek new rail and rapid bus lines with attractive stops and stations are typically faster than local buses, and are thought to have a far better shot at luring drivers out of their cars.

In recent years, this attractive promise has prompted more than three dozen cities around the US—from Atlanta to Los Angeles to Washington, DC—to build new rail transit lines and expand existing ones. However, this rail development often comes at the expense of bus service, which is less glamorous but essential for the mobility of many, particularly the urban poor. Since 2001, inflation-adjusted rail transit capital and operating subsidies per urban resident rose 16 percent, while equivalent bus subsidies per resident actually fell 4 percent. This focus on increasing transit vehicle speeds between more attractive stops and stations is not exclusive to rail; the recent wave of busway and bus rapid transit investments has been driven by similar goals.

Hate to Wait

But is spending a lot of money on new, faster trains and buses—along with capital-intensive stops and stations—the best way to increase transit ridership? Recent declines in public transit productivity and the research we discuss here suggest that it is not. Travel by public transit involves more than just riding in buses and trains. A typical door-to-door trip entails walking from one's origin to a bus stop or train station, waiting for the vehicle to arrive, boarding the vehicle, traveling in the vehicle, exiting from the vehicle, and then walking to one's final destination. In many cases, the trip involves transfers: travelers alight from one transit vehicle, move to a new stop or platform, wait for another transit vehicle, and board that vehicle. Research shows that the time and energy travelers spend walking and waiting outside of vehicles greatly influence their perceptions of transit travel. Indeed, research suggests that these out-of-vehicle experiences have considerably more influence on travelers' perceptions of transit travel than the time spent *in* vehicles.

As cities have grown more dispersed and auto-oriented, the share of transit trip times spent outside of vehicles has increased. First, simply accessing transit stops and stations can be an ordeal when service coverage and frequency are sparse in far-flung suburbs. In addition, the focus on rail and bus rapid transit investments has created a need for local feeder services, thus increasing the likelihood of transfers between the local and express



lines. As a result, transit travel in the US frequently entails transfers among lines, modes, and operators—approximately 40 percent of transit trips involve one or more transfers.

Over the years, many researchers have examined transit travelers' perceptions of the burdens of walking, waiting, and transferring, both by asking travelers directly about their perceptions and by observing their behavior. These studies have found that, on average, transit travelers view time spent outside of vehicles as roughly three times as onerous as time spent in vehicles, though this value can vary dramatically. Researchers have found that the typical ratio of perceived out-of-vehicle burden to in-vehicle burden lies between 1.5 and 4.5, depending on the characteristics of the waiting experience. Trips where travelers fear for their safety, are waiting in inclement weather, experience unexpected delays, or must wait a very long time all increase the perceived burden of transit travel, often substantially.

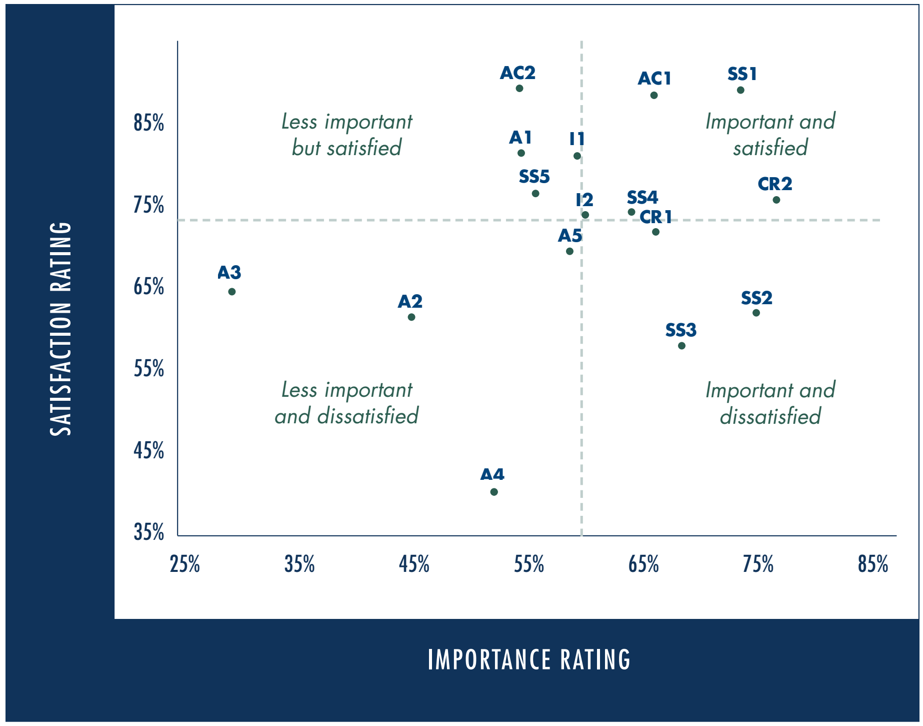
Collectively, these studies suggest that reducing both actual wait times and the uncertainty of waiting may substantially lower the perceived burdens of using transit. Successful efforts to reduce perceived walk, wait, and transfer penalties can have a greater effect on travel behavior than even doubling vehicle speeds with a new rail or busway line, and can be done at a fraction of the cost.

Improving the Wait/Transfer Experience: What Do Travelers Think?

Given this research on the importance of out-of-vehicle experiences to transit users, we asked: What are the best ways to reduce out-of-vehicle travel burdens and improve transit users' experience at stops, stations, and transfer facilities? To address this question, we worked with local transit operators to select stops and stations that were as ➢

FIGURE 1

Attributes Users Find Most Important and Satisfying at Transit Stops and Stations



Amenities
A1 This station/stop area is clean
A2 There are enough places to sit
A3 There are places for me to buy food or drinks nearby
A4 There is a public restroom nearby

Access
AC1 It's easy to find my stop or platform
AC2 It is easy to get around this station/stop

Connection & Reliability
CR1 I usually have a short wait to catch my bus/train
CR2 My bus/train is usually on time

Information
I1 The signs here are helpful
I2 It is easy to get schedule and route information at this station

Security & Safety
SS1 I feel safe here during the day
SS2 I feel safe here at night
SS3 There is a way for me to get help in an emergency
SS4 This station is well lit at night
SS5 Having security guards here makes me feel safer

different from one another as possible—from elaborate multi-modal transit centers to bus stops signified by no more than a simple sign. In total, we selected 34 transit stops and stations in metropolitan areas around California. At these stops, we surveyed 2,247 transit users in the midst of waiting and transferring, at different times and in varying weather conditions, to get a clear and immediate sense of how they felt about their waiting experience. We developed a survey that asked about 16 different attributes reflecting stop and station access, connections and reliability, information, amenities, and safety and security. Attributes included station/stop cleanliness, the absence of graffiti, the availability of information, the provision of seating, etc., as listed in Figure 1.

We asked riders to rate (1) how important particular stop/station attributes were to them, (2) how satisfied they were with these attributes at that particular stop/station, and (3) their overall level of satisfaction with their transfer experience. We then analyzed how satisfied riders were with the attributes they found most important. Figure 1 summarizes the relationship between the relative importance transit users in our sample assigned to each attribute and their level of satisfaction with that attribute.

By combining the importance and satisfaction ratings and then plotting them relative to their averages (indicated by the dotted lines), we classify transfer facility attributes into four categories. First, the top-right quadrant depicts attributes (such as feeling safe during the day) that respondents rated as important and for which they also reported considerable satisfaction. Second, respondents rated the attributes in the bottom-right quadrant (such as feeling safe at night) as important but unsatisfactory. Third, attributes in the top-left quadrant (such as having enough places to sit) were viewed with considerable satisfaction by users, but were also rated as less important. Finally, the bottom-left quadrant displays attributes (such as having a public restroom nearby) that were rated as both less important and unsatisfactory across the diverse set of stops and stations we surveyed.

We also used ordered logistic regression models to examine which attributes of stations and stops best explained transit users' *overall* satisfaction with their transit trips. Again, we found that transit riders tend to care more about personal safety and frequent, reliable service than the physical conditions of transit stops and stations. In other words, our findings suggest that most passengers will opt for safe (even if lackluster) stops and stations with frequent, reliable service over stops with infrequent service and abundant benches, shelters, and other amenities. Thus, improving on-time performance and safety and security measures (such as through the presence of security guards and lighting) are more likely to increase overall satisfaction than adding amenities like seating and shelters. One can think of these attributes in terms of a relative hierarchy of transit users' preferences as shown in Figure 2.

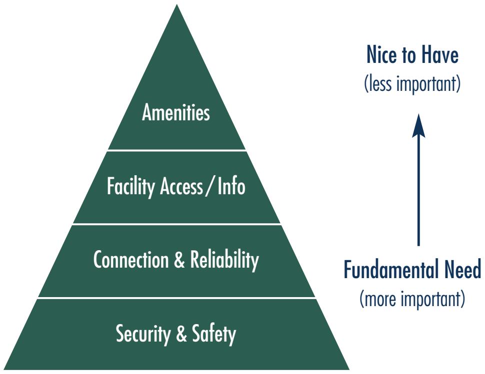
Finally, we analyzed how the duration of wait times affected the importance that travelers assigned to different attributes. In other words, how important are attributes such as benches and shelter as wait times increase? We found that transit riders valued safety and security, service reliability, and on-time performance regardless of whether the wait is expected to be short or long, but the importance of amenities—shelter, seating, restrooms, and nearby food and drinks—increased substantially with longer wait times. While such a finding may seem reasonable, even obvious, it does pose a dilemma for transit planners. Stop and station amenities can be expensive to provide, so transit managers quite naturally tend to put them at high-volume stops and stations where more people can enjoy them. But such high-volume stops and stations tend to have the lowest average wait times and thus are precisely the locations where such amenities are least valued by individual passengers.

What do these findings tell us about current trends in transit investments? We also surveyed transit managers—those responsible for planning and delivering transit services and facilities—to understand whether they perceived the importance of stop/station attributes in the same way as their riders. Nearly two hundred transit managers responded to our inquiry, and we found that managers, by and large, understand what their passengers value and find important. They know that safety and security are most important to a good stop/station, followed by frequent and reliable service. They also understand that comfort and aesthetic factors, though important, rank well below these other more fundamental attributes.

While managers appear to understand their riders, and therefore emphasize functional attributes, such as safety and security, pedestrian/vehicle conflicts, and schedule coordination, their responses to our survey suggest that they tend to focus on the *physical* attributes of transit systems in addressing these functional attributes. But focusing on facility design is potentially misleading, as frequent, reliable service is largely unrelated to the physical characteristics of a stop or station. Research has shown that riders worry more about their safety on the walking, waiting, and transferring portions of transit trips, than any other aspects of transit trips. Thus, riders' overwhelming concern with safety suggests that a central determinant of satisfaction and thus transit use lies partially, and sometimes completely, outside the control of transit agencies, because local governments are typically responsible for the policing of most transit stops. ➢

FIGURE 2

Transit Travelers' Hierarchy of Preferences



Getting More Bang Out of Our Transit buck

Given the importance of walking, waiting, and transferring to the transit travel experience, what does our study suggest for transit managers interested in attracting more riders and improving the effectiveness of transit investments?

First, transit planners and managers should satisfy the most basic building blocks of user preferences before investing in improvements that are less important to riders. Planners and managers should aim to reduce the most burdensome perceived obstacles to transit use by ensuring a safe and secure waiting environment for passengers. Only after this most fundamental need has been met to the degree possible should operational enhancements be made to improve service frequency and reliability. After these needs have been met, improvements to stop/station accessibility are next in line. Finally, only after all of these needs have been addressed can transit managers then justify devoting resources to improving stop and station amenities.

But what's a transit operator to do when faced with limited operating funds that preclude the addition of more frequent service? While our study clearly shows that service frequency and reliability are most critical to rider satisfaction, other cost-effective measures—such as "next vehicle" arrival-time indicators that reduce rider uncertainty—can go a long way toward reducing the perceived burdens of transfers and waiting. Such improvements can be much more cost-effective than building high-capacity, trunk-line services.

"Next vehicle" arrival-time indicators can go a long way toward reducing the perceived burden of transfers and waiting.

Consider the hypothetical example of a four-mile bus trip involving a 10-minute wait prior to a 20-minute ride to the final destination (Table 1, Row A). If the traveler has no information about the likely arrival time of the next bus, research tells us that this uncertainty will add significantly to his or her perceived trip time. One way to make the existing service more attractive would be to install accurate real-time information on the expected arrival time of the next two buses for each line operating at a given stop, and to make this information easily available at the stop and on mobile phones. The actual wait and in-vehicle times don't change, but travelers' information about their expected wait time improves dramatically (Row B). If the cost of the next-bus system is $1 million per mile, the total cost for the four-mile segment is $4 million, and travelers perceive a 15-minute time saving for the trip.

TABLE 1

Hypothetical Example of Reducing Actual In-Vehicle Travel Time versus Reducing Perceived Out-of-Vehicle Travel Time

Transit Service / Improvement	Cost of Improvement	Wait Time *(Actual)*	Transfer Penalty	Wait Time *(Perceived)*	In-Vehicle Time *(Actual= Perceived)*	Total Time *(Actual)*	Total Time *(Perceived)*	Time Saved *(Perceived)*	Cost *(4 miles)*
	(1)	(2)	(3)	(4)=(2)x(3)	(5)	(6)=(2)+(5)	(7)=(4)+(5)	(8)	(9)=4x(1)
A. Local Bus	[baseline]	10 min	3x	30 min	20 min	30 min	50 min	–	–
B. Local Bus with Next-Bus Info	$1 mil/mile	10 min	1.5x	15 min	20 min	30 min	35 min	15 min	$4 m
C. Light Rail	$100 mil/mile	10 min	3x	30 min	10 min	20 min	40 min	10 min	$400 m
D. Light Rail with Next-Train Info	$101 mil/mile	10 min	1.5x	15 min	10 min	20 min	25 min	25 min	$404 m

Another way to make this trip more attractive is to add a new, faster light-rail service operating on a parallel right-of-way (Row C). Free of most delays from operating in mixed traffic, the new service doubles travel speeds, cutting the in-vehicle travel time in half. As before, travelers on this hypothetical new service are given no accurate real-time information on the expected arrival time of their train. If the cost of the light-rail system is $100 million per mile, the total cost of the four-mile segment is $400 million, and travelers experience and perceive a 10-minute time saving for the trip.

In this example, spending $4 million to provide a next-bus information system would reduce perceived travel time by 15 minutes (Row B), while spending $400 million to build a light-rail system (Row C) would reduce perceived (and actual) travel time by only 10 minutes. The next-bus system would cost only 1 percent of the light-rail system, but deliver 50 percent more perceived time savings. This hypothetical example shows how improving bus service can be far more cost effective than even doubling vehicle speeds with a new rail line.

All else equal, the purpose of transit is to convey users to destinations, not simply to make them equally happy at stops and stations. Thus our findings suggest that transit managers, when they have a choice, would be well-advised to favor service frequency/reliability improvements over stop or station improvements. While lower in-vehicle travel times and comfortable, informative, and attractive stops and stations can make traveling by public transit more agreeable, what surveyed passengers report that they really want most is safe, frequent, and reliable service, plain and simple. ◆

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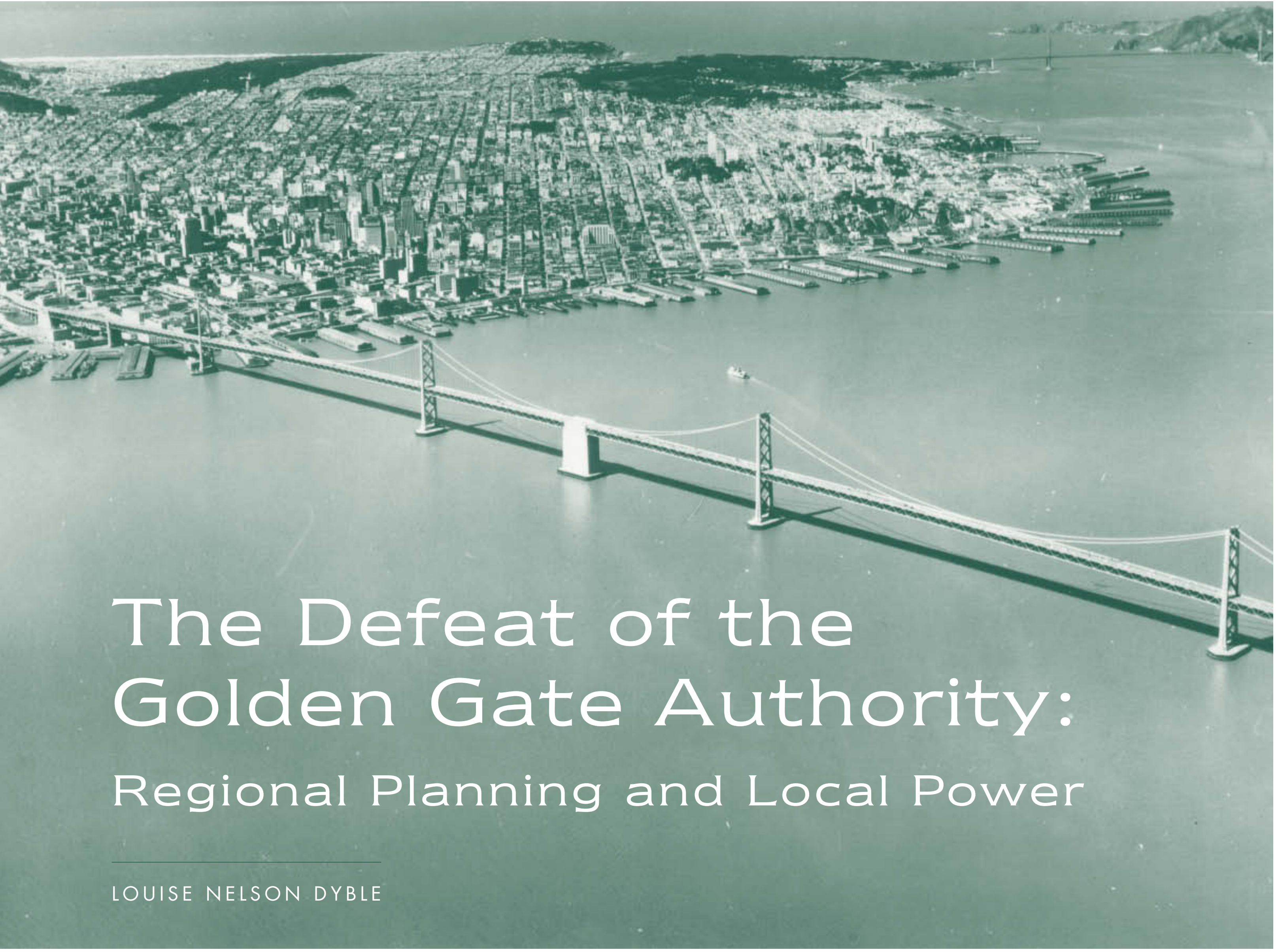

The Defeat of the Golden Gate Authority:

Regional Planning and Local Power

LOUISE NELSON DYBLE

THE MOST AMBITIOUS PROPOSAL FOR TRANSPORTATION PLANNING EVER CONSIDERED FOR THE San Francisco Bay Area—the Golden Gate Authority—went down in defeat in 1962, bringing serious efforts for regional government to an end. Authority advocates touted its potential to promote prosperity, provide employment, and relieve congestion, promises that appealed to many Bay Area leaders and interest groups. However, the prospect of a powerful new transportation authority also garnered strong opposition.

In the decades following World War II, policy analysts and public officials throughout the United States recognized the need to address various problems created by rapid metropolitan growth, including traffic congestion. A virtual policy consensus created a rare window of opportunity to establish new institutions to govern and plan on a regional scale. Proponents of the Golden Gate Authority believed that the agency could centralize transportation policy and eventually provide comprehensive planning for the entire nine-county region. The story of the Authority's failure suggests that the patchwork pattern of decentralized, fragmented government in most American metropolitan areas may be self-perpetuating, with important implications for future efforts to plan and coordinate metropolitan area development.

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For Metropolitan Problems, a Metropolitan Solution

The Bay Area population more than doubled between 1940 and 1960, and the number of automobiles more than tripled. Commuters packed both the San Francisco-Oakland Bay Bridge and the Golden Gate Bridge. Moreover, interregional and international transportation facilities were under severe pressure. Three airports suffered from congestion, five major ports competed for traffic, and all of them were out of date. By the mid-1950s state analysts concluded that inadequate and uncoordinated transportation facilities were hindering development in the region.

The proposed Golden Gate Authority represented the culmination of years of planning by the Bay Area Council (BAC), the region's most powerful civic association representing big business, industry, and labor. The BAC's new president, Edgar Kaiser, led the effort, along with State Senator Jack McCarthy of Marin, who was also chairman of the state Committee on Metropolitan Bay Area Problems. They were an energetic team—a young, ambitious politician partnered with a scion of industry eager to make his mark.

FIGURE 1

Edgar Kaiser Testifying in Sacramento before the Senate Committee on Bay Area Problems on the "Crying Need" for the Golden Gate Authority, March 25, 1959

At Kaiser's behest, the BAC hired Coverdale & Colpitts, a prominent consulting firm based in New York, to develop a detailed proposal for the Golden Gate Authority and to make a case for its value. Their report, describing an independent public corporation, was released to the public in December 1958. The proposed Authority would have a corporate management structure, giving "a business administration to what are essentially business functions," according to the consultants. Following the recommendations of local chambers of commerce, county supervisors would appoint the Authority's leadership. Appointees would head the agency, but a professional staff would be expected to guide policy based on the "facts of growth," thus reflecting the backers' faith in expert administration and engineering objectivity. Financial independence was critical in this plan. New transportation infrastructure would be financed with revenue bonds, reducing the need for state or federal subsidies and therefore limiting outside interference and the need for political negotiations. The staff members would acquire and administer major revenue-generating transportation facilities, and use these assets to finance a wide variety of new projects.

Bridge tolls—which would be the Authority's greatest financial resource—were essential to the agency's independence and efficacy. Bay Area bridges, together worth $225 million in 1957 ($1.8 billion today), represented nearly 60 percent of the Authority's potential assets. The Golden Gate Bridge and the San Francisco-Oakland Bay Bridge (which Kaiser dubbed the "Great Fat Golden Cow") had large surpluses, and together would generate nearly 80 percent of all projected Authority revenue. The California Toll Bridge Authority, a state agency that answered to a legislature and a governor who supported the proposed Golden Gate Authority, controlled all but one of the region's bridges. The Golden Gate Bridge was the exception: it was operated by an independent, special-purpose agency, the Golden Gate Bridge and Highway District. ➢

The consultants designed the Golden Gate Authority to evolve and expand beyond transportation, as Kaiser put it, to "plan for the further development of the Bay Area, not only upon economic and industrial lines, but also . . . to provide residential, recreational and social facilities of value to all citizens." The Coverdale & Colpitts report presented a vision of regional planning in which an independent agency would be empowered to pursue the intensive development sought by Bay Area business and civic elites.

In a press conference following the release of the report, Kaiser praised BAC leaders for accepting their "proper leadership role" by supporting the new regional authority. In the following months, BAC members spoke throughout the Bay Area, and both Kaiser and McCarthy stumped relentlessly. Kaiser also met with the editors of major newspapers who immediately endorsed the proposal, and in February 1959, BAC allies introduced legislation in Sacramento to create the Golden Gate Authority (Figure 1).

Officials of cities, counties, and special districts asserted the intrinsic value of home rule.

Defending Local Autonomy

Opposition to the Golden Gate Authority came almost exclusively from local governments. In an attempt to protect their autonomy, officials of cities, counties, and special districts asserted the intrinsic value of home rule.

Berkeley Mayor Claude Hutchison called a meeting to discuss the Golden Gate Authority in March 1959. Mayors, councilmen, and city managers representing 42 cities and counties attended. The California League of Cities representatives emphasized the importance of local self-determination and opposed any kind of master plan. San Leandro City Manager Wesley McClure offered a scathing critique of the proposed Authority: "It is . . . not merely a monster, but a financially healthy monster, which, with built-in financing from all the lucrative revenue producing facilities of the area, can independently go its merry way . . . without regard [for] local government." Kaiser attended with a prepared speech in hand, but never got a chance to speak.

Attendees passed a resolution requesting that the state legislature delay the bill and formed a new organization to oppose it. The resulting Planning Committee on Metropolitan Bay Area Problems met regularly over the next several months. From this seed of reaction a council of governments grew, intended to derail the proposed Authority by serving as an alternative institution for regional planning (Figure 2).

The other major opponent of the proposed Authority was the Golden Gate Bridge and Highway District. The agency had a reputation as a well-funded bastion of patronage and perquisites, and its directors resolved to defend it. Its general manager made use of a generous expense account to lobby legislators in Sacramento. Directors campaigned around the Bay Area and convinced Sonoma, Mendocino, and Napa counties to oppose the Authority.

Golden Gate Bridge representatives also convinced San Francisco supervisors that the Authority would undermine their influence over transportation policy and result in higher tolls. After months of discussion, the supervisors called for nine amendments including a guarantee that they would appoint half of the Golden Gate Authority's directors. This was a deal-killer; Alameda County in the East Bay had about the same population as San Francisco, and Oakland's leaders would never agree to let their biggest rival dominate.

During the 1959 legislative session, state lawmakers added more than a hundred amendments to the bill in an attempt to answer all local objections to the Authority.

FIGURE 2

San Francisco Chronicle
February 11, 1959

By the time Governor Pat Brown went on record in favor of creating the Authority, it was already too late. *San Francisco Chronicle* editors commented that "the demise of the Authority proposal—as amended and reamended by the Legislature—may prove a mercy killing…. [It] was so thoroughly emasculated in terms of representation, of power, function and duty, that enactment might have created more problems than it solved."

Hearings in the Bay Area

Following this defeat, Golden Gate Authority proponents geared up for a new effort in 1961. At end of the 1959 legislative session, the Legislature created a study commission made up of Authority supporters. Twelve public hearings revealed that the Authority could easily acquire most transportation facilities, including ports and airports in Oakland, Redwood City, San Jose and San Francisco. Overall, testimony was positive and suggested strong public support. Most objections came from local officials who were concerned about the terms of acquisition for individual facilities. The California Director of Public Works remarked that the Authority should not be compromised by petty local protests and pledged to support the transfer of state bridges to the Authority.

The most contentious hearings revealed that Golden Gate Bridge officials opposed the Authority most resolutely. George Anderson, an elderly director who had promoted the bridge in the 1920s, read a lengthy statement against the Authority. He cited the rights of the bridge's original bondholders and the reduction (or elimination) of representation for bridge district counties as reasons to oppose the bill. When asked hostile questions by commission members about the bridge district's large staff, well-paid executives, ➢

and costly maintenance, however, he offered no real defense. Commissioners also pointed out that none of the bridge district's large reserve funds or surplus revenue was being reinvested, and made it clear that they were determined to take over the bridge and use its tolls for regional development.

The *San Francisco Examiner* followed the hearings with a three-day series detailing extravagance and waste at the Golden Gate Bridge and Highway District. Undeterred by negative publicity, bridge district officials continued their fight. One radio commentator remarked: "It seems likely that the district directors feel that they have built up a tidy little empire and, by gum, they don't want to let it go."

"The district directors have built up a tidy little empire and, by gum, they don't want to let it go."

In the meantime, local government officials who opposed the Authority developed an alternative proposal for regional government. At the final hearing, Berkeley Mayor Claude Hutchison introduced a proposal for an Association of Bay Area Governments (ABAG). The organization would be comprised of a single representative from each city and county. Its members would discuss problems and develop recommendations, but would have no power to take any action. Authority advocates were immediately antagonistic to ABAG. Economist Thomas Lantos pointed out that the creation of ABAG would contradict one of the basic goals of the proposed Authority, "to curb the [influence] of cities and counties in regional matters." In addition, Lantos objected that ABAG's representation would have no relationship to population, and would represent the interests of governments rather than people. Hutchison responded that ABAG's lack of power made representation immaterial. Although his toothless proposed association garnered ridicule from the commission members, he nevertheless began enrolling members.

Overall, the hearings represented a success for Authority proponents. The counties of Alameda, Contra Costa, Marin, San Francisco, San Mateo, and Solano all went on record supporting the Authority. Editors of all major Bay Area newspapers endorsed it as well. The Senate bill had backing from 25 authors (out of 40 Senators), including most of the Bay Area delegation. By all indications, public opinion, as well as the majority of the state legislature, supported the Golden Gate Authority.

Local Interests versus Regional Planning

One Marin County commentator predicted that, as the effort for a regional agency intensified, "the [Golden Gate] bridge folks will come out swinging." And indeed, the bridge directors expanded their public campaign against the Golden Gate Authority. It was their behind-the-scenes activities in Sacramento, however, that ultimately paid off.

The Senate Transportation Committee had to approve the new Golden Gate Authority bill before it could go to the Legislature for a vote. State Senator Randolph Collier, who represented the smallest bridge district county, on the Oregon border, chaired the committee. Known as the "silver fox of Sacramento," Collier was a major advocate for state highway construction. He also had a direct interest in the Golden Gate Bridge. Not only was Del Norte County's right to appoint a Golden Gate Bridge director a rare sinecure for Collier's small rural district, but his constituents also had large contracts for bridge advertising and public relations. Politically, he needed to defend those benefits. In addition, Collier's consistent and effective defense of bridge district interests in Sacramento were no doubt well-rewarded from the agency's large budget for lobbying and campaign contributions.

On provincial grounds, Collier objected that the proposed Golden Gate Authority would "take millions of dollars of state property and turn it over, [giving] no one in the rest of the state any voice in the matter at all." When committee hearings commenced, Collier welcomed bridge defenders testifying against the Authority. He refused to limit the length of presentations against the bill or to allow hostile questioning, repeatedly cutting off McCarthy, a member of the committee. Some proponents of the bill appeared three times before they were heard and many never spoke at all.

After two weeks of testimony, a six-to-six committee vote effectively killed the bill. The result suggested careful orchestration: if it had been defeated outright, it could have been reintroduced. Instead, the committee scheduled more hearings. An Assembly version of the bill passed easily, 54 to 14. It clearly had sufficient support to pass in the Senate as well, but it never made it out of Collier's committee (Figure 3).

Editors of the *San Francisco Chronicle* and *Examiner* blamed Senator Collier and "imperial" Golden Gate Bridge directors for the defeat, and pointed out that the representatives who opposed the Authority represented only 900,000 people while its supporters spoke for nearly nine million.

Bridge district officials honored Collier after the close of the 1961 session with a "victory dinner." He had defended local government by using his Senate committee to defy Sacramento's ruling majority as well as the Bay Area delegation. The state legislature, always a blunt instrument, could more easily obstruct change than facilitate it.

Kaiser finally conceded defeat in 1961, but cited public support for the Golden Gate Authority as evidence that regional cooperation could still prevail. Pragmatically, he also announced that the BAC would endorse ABAG. Kaiser recognized that, although it ➢

FIGURE 3

San Francisco Chronicle
June 11, 1961

was intentionally designed to undermine regional planning, ABAG was now the only means of providing it.

ABAG's structure and rules served the interests of the local government officials who created it. ABAG could only "study metropolitan area problems" and make recommendations. Yet, its existence thwarted attempts to create any more authoritative regional entity. When the Metropolitan Transportation Commission (MTC) was created to fulfill federal planning requirements in 1971, it was similarly powerless, lacking the resources or initiative to shape regional transportation in any meaningful way.

At the time of its creation, ABAG was one of seven regional councils of governments (COGs) in the United States, but by 1972 there were more than three hundred. Like ABAG, many prevented more authoritative agencies from infringing upon local sovereignty as new regional planning requirements were introduced in the 1960s. Among planning advocates, COGs became notorious obstacles, serving as local government bulwarks against outside interference. Their lack of power was fundamental to their purpose.

Conclusion

The window of opportunity to create meaningful regional government closed in the 1970s, both in the Bay Area and around the country. Ideological and intellectual change resulted in growing support for decentralization and market-based governance. But a half-century later, scholars and policy analysts are again advocating for regional coordination and planning. New imperatives will no doubt inspire and create opportunities for metropolitan area regionalism in the 21st century, especially if federal and state governments continue to falter. However, the defeat of the Golden Gate Authority suggests that decentralized governmental structures represent a formidable obstacle to reform. In the Bay Area, the collective resistance of local governments thwarted a popular proposal backed by a unified civic elite, thus demonstrating the power of local governments.

The BAC designed the Golden Gate Authority to promote the interests of big business and industry, and the proposal had significant shortcomings. Nevertheless, the capacity to shape transportation and other policies at the regional level in order to address economic, social, and environmental problems was and remains critical for sound metropolitan area development and competitiveness. While Golden Gate Authority backers were able to rally political and public support, they were unable to effectively navigate the complex decision-making process in Sacramento or to counter behind-the-scenes obstructionism in the Bay Area.

More recently, strategies for regional reform have sought to ameliorate local opposition by reducing the authority and scope of proposed new agencies. However, local governments are never likely to voluntarily compromise their autonomy or to acquiesce to authoritative regional government. Regional planning advocates might achieve better outcomes by focusing on overcoming structural obstacles and defeating their opponents than by weakening their proposals for regional governance. ◆

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Dynamic Ridesharing

ELIZABETH DEAKIN, KAREN TRAPENBERG FRICK, AND KEVIN SHIVELY

MOST CARS CAN CARRY AT LEAST FOUR PASSENGERS, BUT THE AVERAGE auto occupancy rate for all trips in the US is only 1.6 persons. Because all the empty seats in cars represent our greatest source of untapped transportation capacity, promoting ridesharing is of considerable interest. Government agencies across the country employ ridesharing programs both to provide transportation at low cost and to reduce traffic congestion and the other costs of solo driving.

The rigidity of conventional ridesharing arrangements, which generally require fixed travel times, presents a barrier to many people. But developments in computing and communications, however, now allow drivers and potential passengers to match up with little advance planning and no long-term commitments. Local governments, private companies, and nonprofit organizations alike have been pursuing this "dynamic ridesharing" strategy. Participants in these programs use cell phones or computer messaging to match up "on the fly" or up to several days in advance. Travelers submit a ride offer or request and a ridematching service automatically scans its database to identify other offers and requests for trips with similar origins, destinations, and arrival times. If a satisfactory match exists, the service notifies the driver and rider(s) so they can confirm the trip plans. ➢

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Dynamic ridesharing offers carpoolers considerably more flexibility than conventional programs. Travelers can offer or request rides just minutes before their desired departure times, or make scheduled appointments for one-time, one-way trips. This flexibility eliminates the need to commit in advance to a fixed schedule or to travel with particular individuals on an ongoing basis. Travelers who want a ride, or are willing to offer one, need only send an electronic message by phone or computer to a web-based data service, which will provide an instant match based on availability. Recent advances in GPS technology assist drivers and passengers in finding each other during pickups. With some applications there is no charge for riders and no compensation offered to drivers, whereas with others the service compensates the driver using financial information provided by the participants.

At the same time, dynamic ridesharing has weaknesses. Drawbacks include concerns about the safety and security of anonymous matching, as well as problems with stranding riders if they cannot find a match for the return trip. Additionally, program costs and financing, as well as overall program business models, must be considered. Costs include start-up and ongoing operations and staffing, marketing, incentives to participants, software and hardware for rideshare matching, and program monitoring and evaluation. Finally, there are concerns that dynamic ridesharing might pull drivers away from transit and non-motorized modes and into cars, a mode shift that might benefit program users but not the broader community.

Travelers can offer or request a ride just minutes before their desired departure times.

Registering drivers and passengers, and verifying insurance and driving records, can reduce safety concerns. Marketing the services only in high-demand areas, providing extra incentives to offer rides home, or offering a guaranteed ride home either on transit or by taxi can address the problem of stranded riders. Despite these potential solutions, however, the record of dynamic ridesharing to this point has been mixed. Early programs in the 1990s were unsuccessful, but more recent programs in the Minneapolis-St. Paul area and the San Francisco Bay Area had better results. To try to determine whether and how this success can be replicated, our team at the University of California at Berkeley recently conducted a feasibility study to assess the potential for a dynamic ridesharing program in Berkeley.

Setting the Context

The study focused on commuters to UC Berkeley's central campus and to downtown Berkeley, a ridesharing market that includes over 30,000 workers and 40,000 students in an area of about two square miles. After reviewing lessons learned from previous trials of dynamic ridesharing, we carried out a statistical and geographic analysis of the downtown Berkeley travel market, including the university campus. We also held a series of focus group discussions with area commuters and surveyed potential users on their current travel choices and preferences, their interest in dynamic ridesharing, their views of a variety of program options and incentives, and their potential use of a dynamic ridesharing program.

Downtown Berkeley's carpooling mode share for work trips is 5 percent, about half that of the Bay Area as a whole, but this low number is due to the attractiveness of alternative modes. The area has unusually high rates of walking, biking, and transit use, which push down both the drive-alone and carpool shares. Only about 12,000 commuters (less than 20 percent of the market) drive alone on a regular basis. One noteworthy factor keeping auto travel down is that parking is quite expensive, which in turn makes dynamic ridesharing more attractive than solo driving.

Another important factor for our study is that while workers in downtown Berkeley, and UC Berkeley faculty and staff, tend to travel during the morning and afternoon travel peaks, students travel in less predictable patterns that are distributed more evenly across the day, which makes scheduling ridesharing more difficult.

Feedback from Travelers

To better understand how commuters would respond to dynamic ridesharing, we organized seven focus groups of nearly 60 regular downtown and campus commuters. We also used the focus-group findings to design a survey that we administered both on campus and downtown. The 444 survey respondents were evenly distributed between graduate students, UC employees, and downtown Berkeley employees.

Only a handful of the focus group participants had heard of dynamic ridesharing, though more knew about organized and casual carpooling. When told of the program's characteristics, the current carpoolers in the survey and focus groups reported they were the most likely to try, and regularly use, a dynamic ridesharing service. Drive-alone commuters in many cases indicated a willingness to use a dynamic ridesharing service, particularly if it was easy to arrange, and they did not have to commit to traveling home with the same person(s). Some commuters said they would be willing to offer rides every day; many said they would likely use the service occasionally (a few times a month).

Auto commuters expressed more interest in trying or using dynamic ridesharing than those who use transit or non-motorized modes such as bicycling and walking. However, many transit riders said they would use dynamic ridesharing if it proved to be cheaper than rail service (BART) and more reliable than bus transit. In contrast, most pedestrians and cyclists were satisfied with their commutes and not inclined to switch to carpooling, due to the short duration of most walking and biking trips. The extra trip time added by ridesharing would constitute a major addition to overall travel time. Even those with longer trips did not want to wait or divert from their route by more than a few minutes.

For commute trips, travelers reported they would prefer to use dynamic rideshare matching to schedule ride offers and requests in advance of their desired travel date and time, or to place standing requests for a rideshare partner at regular times each week. They were concerned that "last minute" offers and requests would create unwanted obligations or would simply not work. For the most part, they were more interested in the ability to find matches on a part-time or occasional basis than in doing so instantly. ➢

Why Rideshare?

Prospective participants said they would share rides primarily to save time and money and, secondarily, to reduce the environmental impacts of driving. To save time, most would prefer a service that matches riders and drivers automatically, based on stated criteria, rather than one that gives the participant a list of contacts and expects them to follow up. Some were also interested in participating to find regular carpool partners.

Participants differed on whether or not they would expect a rider to pay for a share of the trip's cost, including parking. Some saw it as fair and others saw it as a potential hassle. Some prospective riders expressed a willingness to pay the equivalent of a transit fare to share a ride as a passenger, but drivers suggested that the employer or city should provide free or deeply discounted carpool parking to participants, with the number of passengers increasing price discounts. Such a benefit would have a much larger cost impact than sharing gasoline costs or paying the equivalent of a transit fare, since parking on campus or downtown runs from $6 to $15 a day.

Participants would share rides to save time and money and, secondarily, to reduce environmental impacts.

The survey also sought to understand why travelers would *not* use dynamic ridesharing. As noted above, the most frequently cited reason was a concern that their commute trip was "too short for ridesharing to be convenient." This reason was followed closely by related concerns about the time needed to (1) wait for rides, (2) pick up and drop off passengers, and (3) arrange shared rides.

Some participants were especially concerned that they would not get a ride home, making them anxious and unwilling to use the system regularly. A number of participants said they would be more inclined to use instant ridematching for spontaneous, but discretionary, non-commute trips, partly because they would be less concerned about the timing and occasional delays or missed rides.

Participants less frequently cited safety concerns as an impediment to ridesharing, but some did raise this issue. Most commuters saw a safety and security benefit to having all users register with the ridematching service provider, or the sponsoring organization, prior to arranging rides. Most also preferred anonymous pickup and drop-off points such as parking lots or major intersections, as opposed to home or work addresses.

Commuters also wanted the option of setting their own criteria for rideshare partners, pickup locations, length of wait, and other aspects to enhance their own comfort (for example, some women wanted to ride only with other women.)

To overcome doubts, the study asked participants which incentives might persuade them to rideshare. Respondents most favored free or discounted parking, access to preferred parking lots (including those located nearest to one's destination), and a guaranteed free ride home by taxi in case of emergency or if a carpool is not available. With favored incentives, stated willingness to use the service one or more days a week rose from about 20 percent of the respondents to about half, and from 30 percent to 70 percent of the drive-alone commuters.

Mapping the Market

To assess the potential market for dynamic ridesharing, we also conducted a geographic analysis of commuter travel using data from recent surveys of UC Berkeley students, faculty and staff. The goal was to determine the number of trips suitable for dynamic ridesharing, if such a service were available. We identified the home location of all solo drivers to the campus who had reported that their preferred alternative to driving alone would be carpooling or a shuttle from remote parking. This group numbered about 1,850 commuters.

We then simulated whether the driver could find a rideshare match at least 60 percent of the time with no more than 10 additional minutes required to match schedules or to travel for pickup and/or drop-off. We also simulated "matches" to estimate the likelihood that each traveler in our potential participant sample would offer or seek a ride on a particular day, and to determine the time of day of the offer (within a 15-minute time slot). Then, for offers within the same time slot, we used mapping software to estimate the total extra time required to make the match. If a match could be made within the 10-minute extra time limit, we counted it as a potential success. The typical weekday (Tuesday, Wednesday, Thursday) yielded approximately 850 such potential successes with 10 percent fewer successes on Monday and 20 percent fewer on Friday.

Next, for travelers whose commute route passed a park-and-ride lot, which can provide a convenient location for carpool partners to meet, we determined whether matches could occur at the lot with no more than 10 minutes added travel time. The use of the park-and-ride option added approximately 325 additional potential successes to the participant pool.

Using these two methods we estimated that just under 1,200 potential participants lived in locations and traveled at times that would lend themselves to successful dynamic rideshare matches at least 60 percent of the time. Just under 700 of the potential participants were outside of walk, bike, and transit zones, which we defined as areas within two miles of campus, a quarter mile of a high-frequency bus route, or a half mile of a BART station. Such a program could remove several hundred cars a day from the streets and parking facilities in the city and campus core. ➢

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The Shared Road Ahead

The Berkeley case has many of the elements that make ridesharing attractive: a major destination, priced and regulated parking (with discounted parking prices for conventional carpool commuters), employers willing to offer ridesharing incentives, and other options for rides home should ridesharing not work for a particular trip. Our research shows that dynamic ridesharing does have potential to attract new rideshare trips and reduce solo driving, even in an area like Berkeley, which has an already high use of collective and non-motorized travel modes.

Despite its potential, however, dynamic ridesharing has issues that may limit its efficacy. First, we find that most who expressed interest in dynamic ridesharing would use it only occasionally. Whether such occasional use would be sufficient to keep commuters coming back to the service remains to be seen.

Second, cost savings are a major incentive for commuters to use the service, but many see cost sharing where passengers pay for a portion of the cost of the trip as inconvenient. Only a demonstration project could determine whether cost sharing is worth the effort.

Third, most users would go only a small distance out of their way or wait a short time in order to obtain or offer a ride. Dynamic ridesharing, therefore, requires a relatively dense area to capture a significant share of the travel market.

Fourth, transit riders are a potential source of many dynamic ridesharing customers. However, there are public policy questions about the advisability of facilitating ridesharing among those who are currently using transit, biking or walking. Increased ridesharing could undercut transit ridership without reducing transit operating costs unless the mode shift is large enough to allow transit operators to reduce service levels. Also, if dynamic ridesharing entices bikers and walkers to become carpoolers, it could increase congestion and pollution; if bikers and walkers are not included, however, the market size for dynamic ridesharing shrinks considerably.

The large range of costs for a dynamic ridesharing program would necessitate public and private institutional support. However, dynamic ridesharing need not be a stand-alone service. Ridesharing programs could, for example, partner with transit agencies to provide interested participants with information about other ways to make the same trip, such as on transit. Combining marketing for dynamic ridesharing with a larger program of travel assistance could reduce the costs of offering it as a travel option. In addition, program costs would be balanced by important social benefits, such as reductions in vehicle-miles traveled, greenhouse gas emissions, auto ownership, out-of-pocket traveler costs, and parking. A rigorous benefit-cost analysis is needed here.

Emerging technologies may make dynamic ridesharing more available even in the absence of government- or employer-sponsored programs. The last several years have seen major advances in cell phone, GPS, social networking and instant communication technologies. Ridematching apps have already appeared for long distance trips, e.g., from Berkeley to LA. New apps for local dynamic ridesharing also are evolving. As these apps mature, the public sector's role may become simply to facilitate private sector innovation in dynamic ridesharing by providing information on its availability and perhaps providing incentives for its use. ◆

Can Public Transportation Increase Economic Efficiency?

MATTHEW DRENNAN AND CHARLES BRECHER

IN THEORY, PUBLIC INVESTMENTS IN MASS TRANSIT CAN MAKE URBAN economies more efficient by enhancing employers' access to a larger labor pool at lower transport costs. Moreover, as first explained by Alfred Marshall, the concentration of economic activities in urban areas yields efficiency gains due to agglomeration economies. That is, each firm produces advantages that are shared by all firms located in the same area. The concentration of many businesses can thus produce many such external benefits. Can public transportation increase agglomeration economies?

Over the past few decades, many studies have attempted to measure the effects of agglomeration economies on labor productivity and wages. Few studies, however, have employed rent data to infer the presence of agglomeration economies or to measure how much external benefits increase economic efficiency. Since both capital and labor are inputs in production, the return to capital should reflect the economic efficiency of an urban area just as wages do. Thus, money invested in an area with higher external economies should generate higher returns on capital.

Agglomeration Economies

Office-based activities such as finance, law, accounting, advertising, information technology, and media employ much of the workforce in most large cities. The major capital input in such activities is office space. We use office rents to measure external economies and agglomeration benefits because these rents reflect the return to a key capital input in urban production, commercial office space. Simply put, areas with high concentrations of economic activity and external economies should have higher rents. ➢

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If public transit makes urban areas more efficient by promoting the economic benefits of agglomeration—through reductions in transportation costs and increases in mobility—all else being equal, these benefits should be evident in higher urban rents for office space. Our hypothesis was that office rents, as indicators of efficiency gains from the presence of urban agglomeration economies, will be higher in areas better served by mass transit.

Good mass transit enables large numbers of skilled workers to live in or travel to a small area. Such concentrations of workers increase the likelihood of agglomeration economies of two types: labor pooling and knowledge spillovers.

Labor pooling is the high concentration of workers with specific skills in an area. If firms that use highly specialized labor (such as attorneys experienced in corporate bankruptcies) lose key employees, they are far more likely to find replacements quickly if they are located near other firms that employ such workers. Good public transportation increases the distances specialized workers can travel and increases the area from which firms can draw these workers.

Good mass transit enables large numbers of skilled workers to live in or travel to a small area.

Knowledge spillovers refer to the informal sharing of information among those engaged in the same occupation, whether it be stonework or computer software. Good public transit should increase the ability of workers to connect with others in their fields, increasing the level of knowledge "in the air." Greater concentrations of workers in similar fields make fruitful exchanges more likely. High public transit use makes such concentrations possible and should increase the likelihood of agglomeration economies.

The Data

We use real estate data from Torto Wheaton Research and public transit data from the National Transit Database (NTD), plus government sources for economic data. Our sample of 42 Metropolitan Statistical Areas (MSAs) contains 118 real estate markets with over one million square feet of office space, observed over 17 years, from 1991 to 2007. The variables for each market are annual average gross rents per square foot of commercial office space, the supply of space in millions of square feet, the vacancy rate, and the amount of occupied space. Because there are at least two real estate markets in each MSA, the traditional downtown market is designated as the central business district (CBD) and the other(s) as suburban. The NTD annual data are organized by MSA, and we use annual transit passengers per capita in an MSA as a measure of transit service.

The 118 real estate markets in our sample encompass 85 percent of US commercial office space, with each market containing at least one million square feet of space. All markets are within the boundaries of the 42 MSAs and do not overlap.

Table 1 ranks the 42 MSAs by size in terms of square feet of office space. Thirteen of the 14 largest MSAs have rail transit systems, some extensive, some not. These 14 metro areas (all with more than 70 million square feet of space of office space) account for about three-fourths of the space in all 42 areas. Many of the metro areas with more than 70 million square feet have high concentrations of space in the CBD. Generally, cities that were large before the advent of the automobile (such as New York, Chicago, Boston, and San Francisco) have much higher concentrations of space in the CBD than post-automobile cities such as Los Angeles, Dallas, Miami, and Houston. The pre-automobile cities tend to have extensive rail transit systems and built environments that increase the cost of driving—particularly by raising the cost of parking. Thus the ➢

TABLE 1

Office Space and Transit Use in 42 Metropolitan Areas

Metropolitan Areas	Total Space (Mil. sq. ft.) 2007	CBD Space (Mil. sq. ft.) 2007	CBD/Total (%) 2007	Transit Trips Per Capita 2007	Travel to Work by Public Transit 2000
New York-Newark-Nassau-Suffolk	546	362	66%	215	31%
Washington	270	96	35%	88	16%
Los Angeles-Orange-Oxnard	248	34	14%	56	6%
Chicago	219	123	56%	65	13%
Dallas-Fort Worth	166	26	15%	13	2%
Boston	158	79	50%	81	13%
Houston	137	35	26%	18	3%
San Francisco-Oakland	137	59	43%	100	17%
Atlanta	129	29	23%	30	4%
Philadelphia-Wilmington	116	36	31%	74	10%
Miami-Fort Lauderdale	97	13	13%	46	4%
Denver	89	24	27%	38	5%
Seattle	79	40	50%	55	9%
Detroit	71	11	16%	11	2%
Phoenix	68	14	21%	16	3%
Minneapolis	64	29	46%	28	5%
San Diego	55	10	18%	33	4%
Baltimore	51	12	23%	41	8%
Kansas City	47	15	32%	8	2%
Sacramento	42	8	20%	17	3%
Portland	42	16	38%	49	7%
St. Louis	40	12	31%	20	3%
Charlotte	39	14	35%	12	3%
Cleveland	37	19	51%	29	5%
San Jose	37	8	21%	24	4%
Tampa	37	7	19%	9	2%
Austin	34	8	24%	21	4%
Cincinnati	34	13	39%	14	4%
Orlando	33	7	22%	13	2%
Stamford	33	17	51%	12	10%
Indianapolis	31	12	38%	6	1%
Columbus	30	11	37%	9	2%
Nashville	30	7	22%	6	2%
Las Vegas	30	2	5%	40	4%
Salt Lake City	29	10	34%	38	3%
Hartford	26	8	30%	14	4%
West Palm Beach	24	12	51%	46	NA
Riverside	22	0	0%	6	2%
Jacksonville	20	8	38%	9	1%
Albuquerque	12	3	24%	11	NA
Honolulu	12	9	78%	81	9%
Tucson	8	1	15%	19	3%
All MSAs	**3,426**	**1,258**	**32%**	**36**	**6%**

Source: Torto Wheaton Research, National Transit Data and U.S. Census 2000 supply of public transit matters for the concentration of space in the CBD, but so does the price of its substitute: driving.

Is concentrated development, which is a precondition for the emergence of urban agglomeration economies, facilitated by public transit? It is hard to say, but the descriptive evidence of Table 1 suggests so. The three largest MSAs after New York, in terms of total office space, are similar in size: Washington (270 million square feet), Los Angeles (248 million) and Chicago (219 million). They are, however, dramatically different in terms of the absolute concentration of space in the CBD. Washington and Chicago have large CBDs and also have well-developed and utilized rail transit systems, while Los Angeles has neither. The fifth- and sixth-ranked cities, Dallas (166 million) and Boston (158 million), are almost equal in total size, but the Boston CBD has three times as much office space as the Dallas CBD. Again, Boston has a heavily utilized transit system while Dallas does not. Cities without extensive transit systems may have lower concentrations of office space in their CBDs because heavy commuting by private automobile places a de facto cap on how much office space can be accommodated in a region's CBD. For example, in auto-dependent CBDs parking tends to crowd out office space and traffic congestion intensifies as CBDs grow. Another possibility is that a strong transit system, which generally has its hub in the CBD, makes a CBD location relatively more attractive than suburban locations.

Table 1 also shows public transit use and the share of journeys to work by public transit. Per capita transit use (annual passenger trips divided by the metropolitan population) varies enormously among the 42 metropolitan areas, from 215 in New York to 6 in Indianapolis, Nashville, and Riverside. The share of journeys to work by mass transit exceeds 10 percent in only five places. New York is first at 31 percent, followed by San Francisco, Washington, Boston, and Chicago—all in the mid to low teens. Note that concentration of office space in these five cities' CBDs ranges from 362 million square feet (New York) to 59 million (San Francisco), far exceeding that in any other metropolitan area. The data thus suggest a positive connection between the concentration of office space in CBDs and the use of public transit. We suspect that higher public transit use makes possible a much greater concentration of office space in the CBD.

Public Transportation and Agglomeration Economies

We use regression analysis to estimate the effects of public transit use on agglomeration economies, with office rents as the dependent variable. This method allows us to separate the effects of per capita public transit use from other variables (such as the office vacancy rate and the unemployment rate) on office rents. It addresses the question: Do CBDs with high concentrations of office space command higher rents because of higher public transit use?

The tentative answer is *yes*—but not by a large amount. For those CBDs with more than 30 percent of the total metropolitan office space, the effect of transit use on rents is small but positive and statistically significant. For suburbs in those MSAs the effect is similar. By contrast, the results show that transit use has no effect on office rents in places with a low concentration of office space in the CBD.

These statistical results show that public transit appears to increase office rents, our measure of economic efficiency, but only for places with a high concentration (above 30 percent) of office space in the CBD. How big is the increase in rents and does it have any implications for expanding public transit? Our data show that a 10 percent rise in transit use raises office rents by only 0.5 percent. Using the mean office rent of $23.86 per square foot per year in 2007 for all markets, these percentage changes translate into rent gains of only 1¢ to 12¢ per square foot per year.

The policy implication is that rent gains from increasing transit ridership would be a tiny fraction of the cost of expanding public transit in MSAs with a high concentration of space in the CBD. Nonetheless, cities with high transit use and a strong concentration of office space in the CBD may protect existing office rent premiums from competing suburban locations by maintaining levels of service. The five high-transit-use cities (New York, San Francisco, Washington, Boston and Chicago) have much higher rents in the CBD than in the suburbs, and the CBD premium has not been shrinking. In 2007, the average CBD rent of these five cities was $42 per square foot per year compared with $26 for the suburbs. All 37 other MSAs had a premium for CBD office space in the early 1990s, but it disappeared around 1995. Since 2005, suburban rents have been about $1 per square foot per year higher than CBD rents.

Judging from the disappearance of a rent premium for the CBD in most cities, transportation and communication technology may have led to the relative "death of distance" in most metropolitan areas. Rent premiums in the CBD, however, appear to be alive and well in the five places with the highest number of transit journeys to work. Based on our argument that office rents manifest benefits of agglomeration, we infer that in some places public transit use modestly contributes to urban economic efficiency.

What do these results indicate for public policy? Our analysis did *not* show that expanding public transit would achieve large gains in economic efficiency. Even in cities with a high concentration of office space in the CBD, we estimate that increasing transit ridership by 10 percent will increase office rents by no more than 0.5 percent. For all other cities, we estimate that increasing transit ridership will have no effect on office rents. On the other hand, public transportation has many benefits beyond increasing office rents. For example, it can increase access for people without cars, reduce traffic congestion, and improve air quality. It does not appear, however, that increasing transit ridership will significantly increase agglomeration economies. ◆

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THE ACCESS ALMANAC

Solar Parking Requirements

DONALD SHOUP

SOLAR PANELS HAVE BEGUN TO FIND A NEW PLACE IN THE SUN—on parking lots surrounding commercial and industrial buildings, mounted on canopies providing shade for the parked cars. Parking lots in asphalt-rich cities have great solar potential because the panels can be oriented to maximize power production during summer afternoons when electricity is most valuable. Solar-powered parking lots can mitigate the substantial increase in peak-hour energy demand that major developments create, but few developers now install solar canopies over their parking lots. Although the demand for electricity peaks on days when the sun shines brightest, solar power accounts for less than 1 percent of our total electricity supply.

How can cities increase power production from parking lots? They can incorporate solar power into their off-street parking requirements. Cities already specify a minimum number of parking spaces for every building, the minimum size of the spaces, and their landscaping. Cities could also specify that a share of these spaces be covered with solar panels to meet the increased peak-hour power demand created by new buildings.

The rationale for requiring solar power in a parking lot resembles the rationale for requiring the parking lot itself. Because new buildings increase the demand for parking, cities require parking spaces to meet this demand. Similarly, new buildings increase the demand for electricity during peak hours, and a solar requirement for the parking spaces will help to meet this demand. Because the air conditioners for new buildings increase the risk of neighborhood power failure on hot summer days, it seems reasonable to require developers to offset this risk.

Cities can amend their zoning codes to require solar power in the parking lots of new buildings. Requiring a specific electric generating capacity, such as 1 kilowatt per parking space, will give developers the freedom to meet the requirement in the most cost-effective way. (Covering one parking space with solar panels will produce about 2 kilowatts of generating capacity, so covering half the spaces in a parking lot will produce about 1 kilowatt per space.) Because the solar potential of a parking lot depends on many factors, such as climate and topography, solar power requirements would differ among locations and land uses, just as off-street parking requirements do. Cities should not adopt solar requirements in all locations and for all land uses, but sunny areas with large parking lots are a good place to start. Cities can also offer developers who prefer not to install solar panels on their parking lots the option to pay for equivalent renewable energy or conservation measures elsewhere, perhaps at a school or other public building.

Solar arrays will not mar the appearance of parking lots because most parking lots are already ugly. Solar canopies, which resemble hi-tech trellises, can improve the appearance of most parking lots and become an important architectural feature of a building. They can also help to reduce the visual blight and NIMBY problems associated with building power plants and transmission lines.

If each solar canopy has an electric-vehicle charging station at its base, the solar parking requirement will help to distribute charging stations throughout the city. In California, one solar-covered parking space can generate about 5 kilowatt-hours of electricity a day, which is enough to drive an electric vehicle for about 20 miles. Solar canopies at work can therefore fuel the trips to and from work for many commuters' electric cars. California requires that, by 2025, 15 percent of all cars sold in the state must have zero tailpipe emissions, and other states are adopting similar requirements. Solar canopies over parking lots can provide some of the electricity needed for these cars without straining the grid's generation and distribution systems.

The intermittent nature of solar power output makes it well suited to charging electric cars. If the solar energy is being stored in batteries rather than fed into the electric grid, the power fluctuations caused by clouds will not cause stability problems for the grid. The solar power output can also directly charge batteries without the power loss caused by conversion to alternating current for the grid.

Solar parking lots are highly visible evidence of a company's commitment to the environment. If the parking lots at new buildings come with solar canopies, vast parking lots without solar panels could begin to look antisocial. The owners of some older buildings might update their parking lots with solar arrays to keep up with the green look of the new competition. Even drivers who don't own electric cars can feel green when they park in the shade of solar panels.

The federal government and many state governments provide generous subsidies for solar panels, so developers will not have to pay the full cost of complying with a city's solar parking requirement. Because parking lots are usually bigger than the buildings they serve, and usually have unobstructed solar access, the solar panels can take advantage of economies of scale in construction and can capture more of the available sunlight. In contrast, few houses have properly oriented roofs, unobstructed solar access, and the structural capacity to support solar panels. Therefore, parking lots will generate more electricity per dollar of government subsidy than houses can.

Solar canopies not only produce power but also reduce the demand for it. Shading parked cars will reduce the use of air conditioning by motorists when they leave the solar parking lots on sunny days, resulting in better fuel efficiency and reduced tailpipe emissions. The canopies can also reduce the heat island effects of parking lots around buildings, and thus reduce air conditioning demand in the buildings.

Beyond their economic advantages, solar-powered parking lots will be a decentralized source of back-up electricity in an emergency, such as a natural disaster or terrorist attack. Reducing the demand for energy from the electric grid will also reduce power plant emissions that contribute to air pollution and climate change. Some states require electric utilities to obtain a specific share of their energy from renewable sources, and solar parking lots can help satisfy these requirements.

Solar panels in parking lots will start producing power far sooner than conventional power plants, which take years to construct. Solar parking lots distributed throughout the city will also generate electricity right where it is used, reducing transmission losses on the power grid and helping to prevent power outages caused by overloaded transmission lines. Because solar panels produce the most electricity on sunny days when the demand for air-conditioning peaks, they reduce the load on conventional power plants at the most critical time.

With only a slight change to the parking requirements in their zoning ordinances, cities can lead the way toward a future powered by renewable energy. We shouldn't wait until the next heat wave to think about getting solar power from our parking lots. ◆

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