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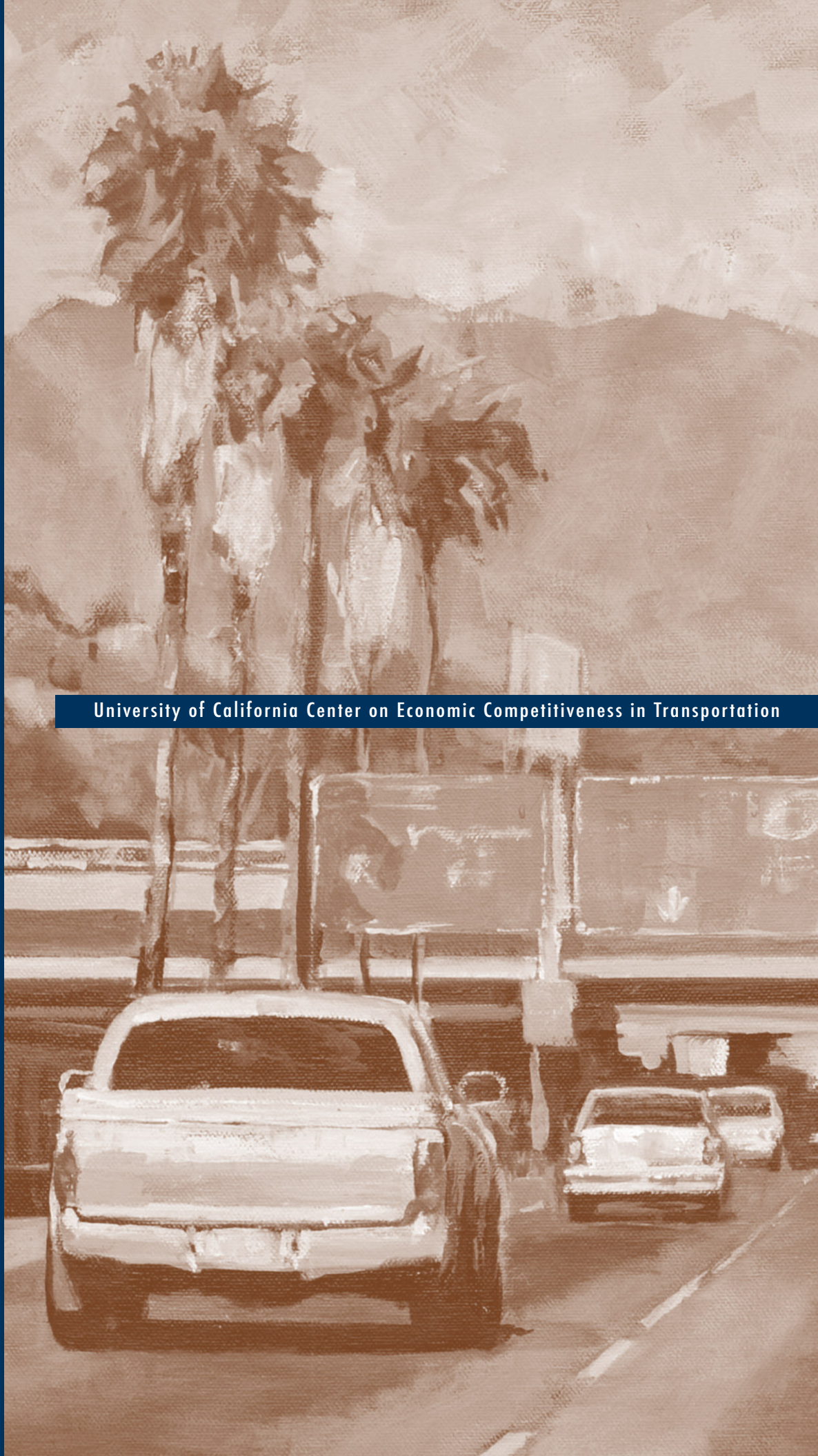
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ACCESS Magazine reports on research at the University of California Center on Economic Competitiveness in Transportation. The goal is to translate academic research into readable prose that is useful for policymakers and practitioners. Articles in ACCESS are intended to catapult academic research into debates about public policy, and convert knowledge into action.

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The Road Less Traveled

When I used to think of people biking to work, I pictured sweaty MAMILs (middle-aged men in Lycra) on ultra-light road bikes—riders who finished the Tour de France and then changed for their morning staff meeting. The reality is that not many people who bicycle are professional cyclists. I certainly don't have an ultra-light road bike and a closet filled with polyurethane fiber. I just have my trusty 15-year-old mountain bike, and a cotton shirt or two.

After experimenting with a month of commuting by public transit, however, I wanted to try another experiment: biking my thirteen-mile commute over the Santa Monica Mountains to UCLA. So one Monday morning, I put on a T-shirt, strapped on my backpack, and rode my bike to work.

The start of my journey was invigorating. It felt good to move with a purpose, and I felt more in control of my fate. Then I turned onto Sepulveda Boulevard.

This four-lane gauntlet is wider than some highways, extremely steep, and filled with traffic. Initially, the hills presented the biggest problem. I seemed to keep going up and up until I finally started walking my bike. Despite a fleeting pang of defeat, I was still moving faster than the people driving next to me.

At the road's apex, I got back on my metal horse, passed through a tunnel, and entered the downhill slope of the adventure. I imagined that this section would be the easiest and most joyful part of the trip. As it turns out, it was the most terrifying. For much of Sepulveda, there is no clearly marked bike lane. In addition, the downward slope is where gridlock ends and the race to work begins. Drivers that were now free from traffic sped by me at 70 mph, completely unaware how easily their vehicle could injure, or even kill, a slow-moving man on a 15-year-old mountain bike. My ride didn't feel like an experiment anymore; it felt like a suicide mission.

And that was the biggest deterrent for me riding into work again: safety. I can buy sweat resistant clothes and

build up my muscles to take on the hills. I can even get an electric bike to help me climb the steeper slopes, but none of these amenities matter if I don't feel safe during my ride.

What would happen if Los Angeles had a network of bike lanes separated from traffic? How many more people would bike rather than drive in this safe environment? This question brings to light the main theme of this issue of *ACCESS*: how our environment affects the way we travel.

In "The Social Context of Travel," Michael Smart and Nicholas Klein explore how LGBT communities affect the travel patterns of gays and lesbians living within those communities.

In "The First Big-Box Store in Davis," Susan Handy and fellow authors investigate how a new Target store has affected travel in a community that typically encourages small business development and environmentally-friendly transportation choices.

From parking on lawns to saving parking spaces with trash cans, Donald Shoup explores the informal parking markets of different cities in his piece, "Informal Parking: Turning Problems into Solutions."

In "Suburban Transit in Mexico City," Erick Guerra examines the effect of a new metro line on the travel patterns of suburban dwellers.

In "A Bathtub Model of Downtown Traffic Congestion," Richard Arnott strives to find the optimal traffic density for maximum flow so we can all get to work on time.

And in the *ACCESS* Almanac, "Painting the Present, Imagining the Future," Richard Willson shows us a different perspective on automobile driving through his own artwork.

We hope you enjoy this issue, however you travel.

John A. Mathews
Managing Editor

The Social Context of Travel

MICHAEL J. SMART AND NICHOLAS J. KLEIN

Imagine two young families living next door to one another in an apartment building in the Castro district of San Francisco, one of the most well-known gay neighborhoods in America. The two families are alike in most regards, but one couple is straight and the other is gay. Neither have children. They have similar jobs and incomes, and they both like living in a dense urban environment. Their daily travel patterns, however, are very different. The gay couple's trips to work, shops, restaurants, bars, and friends' houses are more local than that of their straight neighbors down the hall.

In our research, we find evidence that this is not just a hypothetical situation; gay couples living in gay neighborhoods across America *do* stay closer to home than their straight neighbors. Why might this be? We believe that these differences stem from the social context of the neighborhood. Our imaginary gay couple has chosen to live in a neighborhood where a lot of other gay people live. They may already have a network of gay friends and acquaintances in the neighborhood, and if not, they are likely to develop one. Businesses in the Castro cater to them, and gay social and cultural institutions abound. There is even a niche economy that provides jobs to gay people.

The above scenario is only one example where the social context of a neighborhood can influence activity and travel patterns. We call these “neighborhoods of affinity,” where members of a group with strong social ties live and work. Other examples of these neighborhoods include immigrant enclaves and religious communities.

Lesbian, gay, bisexual, and transgender neighborhoods are common in most American cities. (Here, we use the term LGBT to refer expansively to neighborhoods with a distinctly non-heterosexual identity, though in our study we examine only same-sex couples.) While many who identify as gay or lesbian do not live in these neighborhoods, these enclaves continue to be important focal points for the community. Gay and lesbian individuals move into LGBT neighborhoods for a variety of reasons, but research suggests that a desire to be near one another is an important factor. While many straight people live in these neighborhoods as well, their reasons for doing so are less likely to be tied to the neighborhood’s LGBT identity.

For gay men and lesbians, moving to these neighborhoods is about push-and-pull factors. Few are born into communities with already-established gay and lesbian social networks, so moving to an LGBT neighborhood makes it easier to meet other gay men and lesbians for friendships, support, or romantic relationships. These same neighborhoods frequently offer gay- and lesbian-oriented shops, restaurants, bars, organizations, and social services, which further motivate residential concentration. Clustering in particular neighborhoods also allows for economic empowerment and provides a geographic base for political representation. Finally, fear of harassment, isolation, and violence in other neighborhoods continues to shape the neighborhood choices of gay men and lesbians.

Because so many gays and lesbians move to LGBT neighborhoods in order to be near other gays, lesbians, and LGBT-oriented businesses and organizations, we hypothesize that their travel patterns are much more local than those of their straight neighbors. Presumably, their straight neighbors are not as closely tied to the social fabric of the neighborhood. Similarly, we expected to find that gays and lesbians living in straight neighborhoods would have more dispersed activity patterns than if they lived in a gay and lesbian neighborhood.

There is mounting evidence that a neighborhood’s social fabric helps shape some residents’ activity patterns and travel decisions. For example, previous research finds that many immigrant neighborhoods function as cities-within-cities, and that immigrants living in these enclaves are more likely to use transit, walk, and bike. This finding holds even in suburban neighborhoods, where the built environment typically caters to driving. ➤

The gay couple’s
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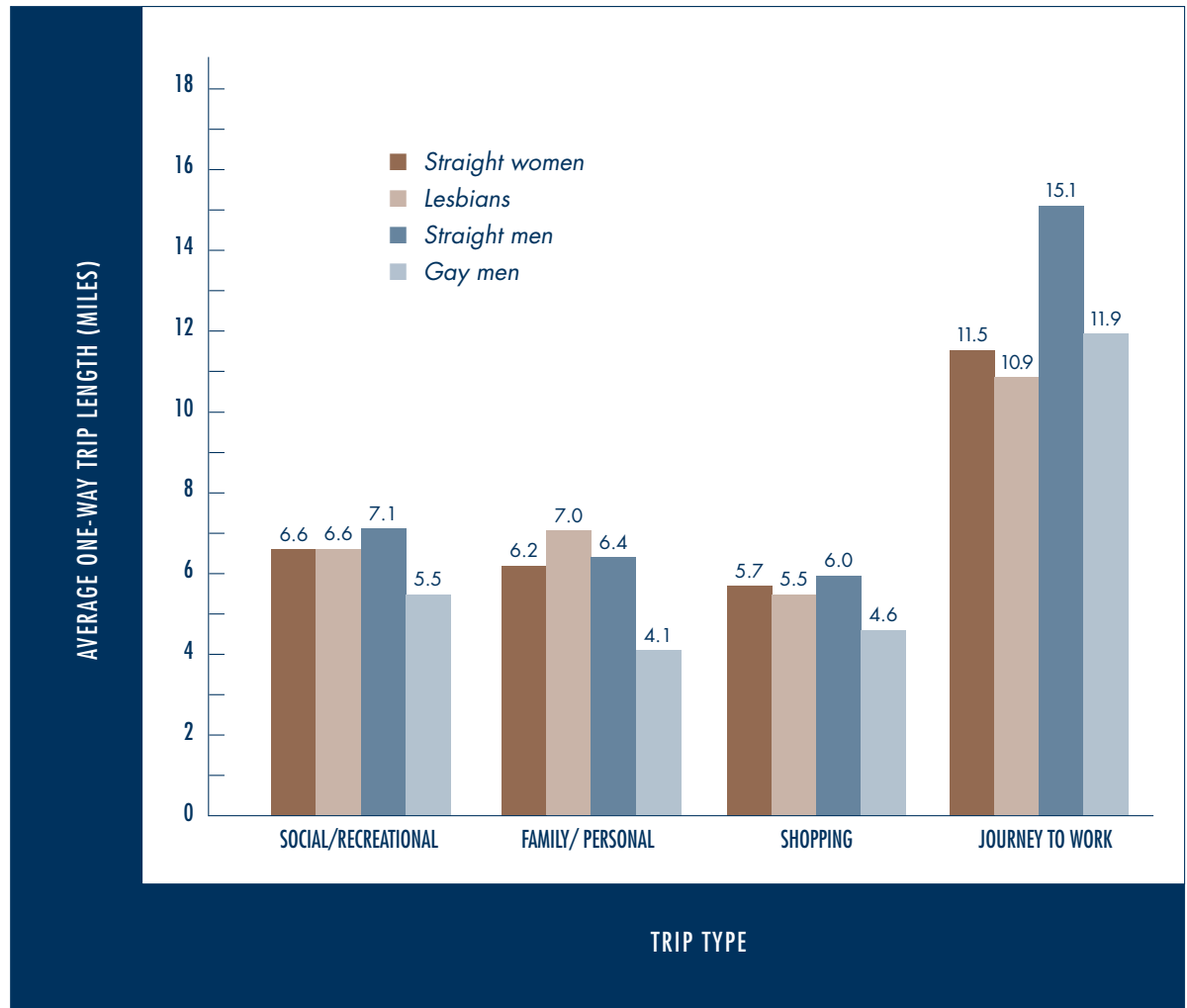
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To study the effect of social contexts on activity patterns, we use data from the nationally representative 2009 National Household Travel Survey (NHTS). This dataset provides information on both households and individuals, and the work and non-work trips they make over the course of a day. Like most large-scale public surveys, the NHTS does not ask questions about sexual identity or orientation. In order to identify gay men and lesbians, we used a common approach, first identifying married or coupled households (distinct from roommates) and then categorizing these couples as either same-sex or different-sex. Because we do not know the sexual orientation for singles, we omitted them from our analysis entirely.

The NHTS data reveal substantial differences in travel patterns for same-sex and different-sex couples, and these differences partially support our hypotheses. Figure 1 shows that gay men, but not lesbians, make considerably shorter trips than lesbians and straight people. The differences are particularly stark for non-work trips.

Of course, gay, lesbian, and straight households tend to be different in other ways as well. These differences may help to explain the variation we observe in travel distance, so we control for them in a series of models. Table 1 summarizes a few of the factors we

FIGURE 1
Average Trip Distances by Trip Type, United States, 2009



	MEN		WOMEN	
	GAY	STRAIGHT	LESBIAN	STRAIGHT
Average household income	\$103,366	\$92,831	\$92,996	\$92,507
Percent of households with children at home	9%	43%	39%	45%
Live in an MSA of 3+ million residents	50%	34%	25%	34%
Density (persons/sq. mi. in tract)	9,510	4,092	3,311	4,007
Density (jobs/sq. mi. in tract)	9,839	1,459	1,907	1,434
Trips per person per day	4.8	4.7	4.9	4.9

TABLE 1
 Characteristics of Gay, Lesbian, and Straight Coupled Households, United States, 2009

examine. For instance, gay men have slightly higher incomes than do straight couples and lesbians. However, gay couples in our sample are far less likely to have children (only 9 percent do in our sample) than are straight (roughly 44 percent) and lesbian couples (39 percent). Gay men are far more likely to work in professional jobs, while lesbians are overrepresented in sales, service, manufacturing and construction jobs. Some of the most striking differences between same-sex and different-sex couples are geographic. Gay men in particular are far more likely to live in large metropolitan areas; just over half live in places with more than three million inhabitants, compared to roughly a third of straight couples and only a quarter of lesbian couples. At the neighborhood scale, gay couples tend to live in much denser areas, both in terms of residents and jobs, than straight and lesbian couples. Finally, gay men own fewer cars, on average, than others.

For gay men, we find that living in a gay or lesbian neighborhood leads to non-work trips that are significantly shorter in distance. Notably, this effect increases as the concentration of same-sex households in the neighborhood increases, and remains even after controlling for other variables such as residential density. Our research suggests that coupled gay men living in neighborhoods where 10 percent of the households are same-sex couples have 53 percent shorter non-work trips than gay men who have no same-sex partnered neighbors. We also find a neighborhood effect for lesbians and straight couples, though it is much smaller than the effect for gay men (Figure 2).

Our results paint a similar picture for the journey to work (Figure 3). On average, gay men work much closer to home when they live in a gay or lesbian neighborhood than when they do not. Gay men living in neighborhoods where 10 percent of the households are same-sex couples work an average of 61 percent closer to their homes than do gay men who live in neighborhoods with no gay neighbors. Again, this effect remains even after controlling for attributes of the individual, household, and neighborhood. For lesbian and straight couples, living in a gay or lesbian neighborhood has no effect on commute trip distance.

This research suggests that, when it comes to travel decisions, being connected to your neighborhood matters. The social fabric of a neighborhood, in conjunction with the built environment, helps shape the activity and travel patterns of people who live and >

FIGURE 2

Distance of Non-Work Trips Compared to Straight Men in Neighborhoods with No Same-Sex Couples

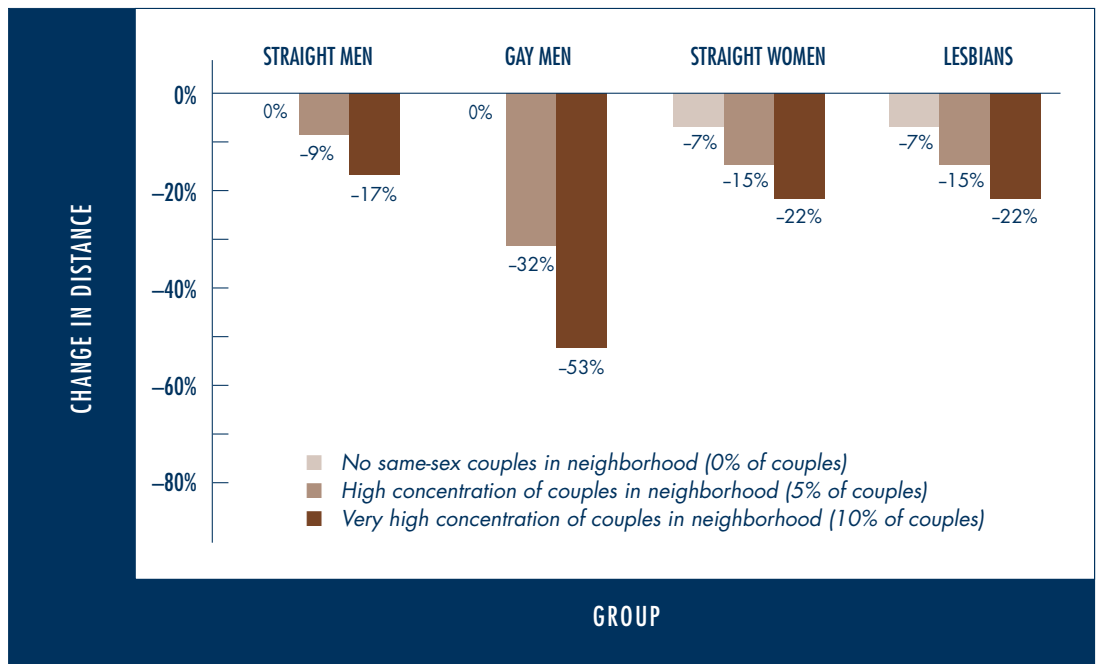
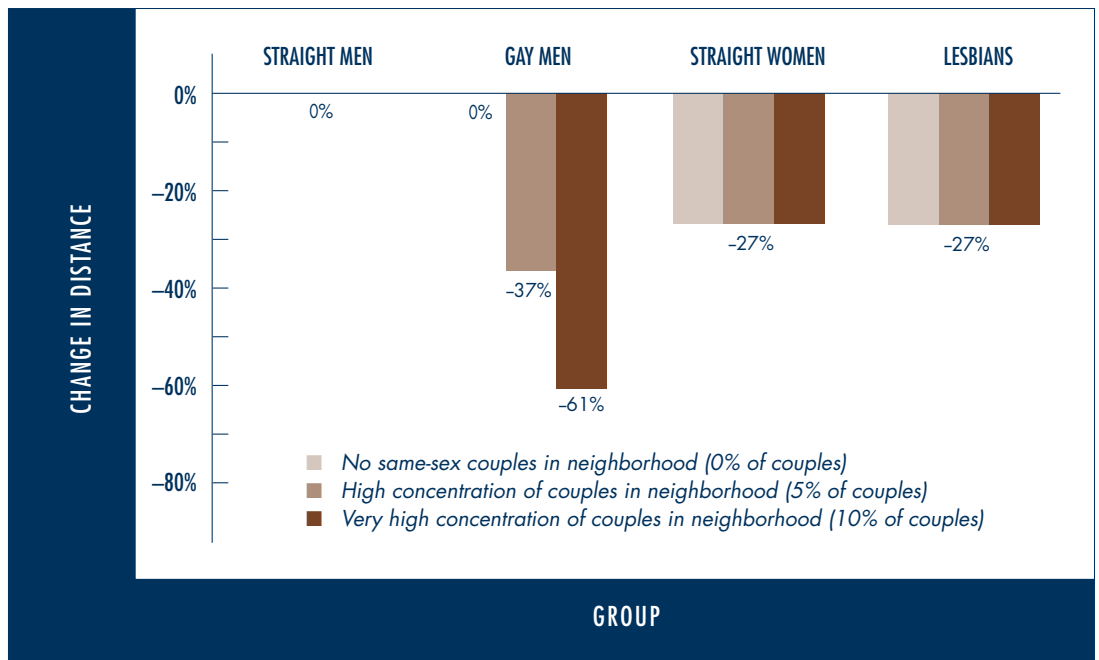


FIGURE 3

Distance of Work Trips Compared to Straight Men in Neighborhoods with No Same-Sex Couples



work there. For urban planners and policy makers, our findings suggest that building a light rail line or investing in bike lanes and pedestrian infrastructure may lead to very different outcomes depending on the community's connection to nearby amenities and their neighbors. Some interventions aimed at increasing the use of alternative modes of travel may even be counterproductive if they disrupt the social fabric of the neighborhood.

Transportation planners too often view neighborhoods principally as physical places, and a great deal of recent transportation research has explored only the connection



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between the built environment and residents' travel choices. Street and sidewalk widths, residential and employment density, tree cover, bike lanes, and other physical aspects of the neighborhood are all linked to activity and travel patterns. While planners also have a long tradition of seeing neighborhoods as social phenomena, transportation scholars have paid little attention to how social networks embedded in places can shape activity and travel patterns. But there is mounting evidence that these forces play an important role in shaping these patterns. The case of gay couples living in gay and lesbian neighborhoods suggests that strong social ties can lead to travel patterns that are considerably more local—something many planners aim to achieve with countless policies and plans. ♦

This article is adapted from "Neighborhoods of Affinity: Social Forces and Travel in Gay and Lesbian Neighborhoods," originally published in the *Journal of the American Planning Association*.

The First Big-Box Store in Davis

SUSAN L. HANDY, KRISTIN LOVEJOY,
GIAN-CLAUDIA SCIARA,
DEBORAH SALON, AND
PATRICIA L. MOKHTARIAN



TARGET COMES TO DAVIS

Davis, California, is well-known in transportation circles for having the highest share of bicycle commuters in the US, due in large part to pioneering efforts starting in the 1960s that created an extensive bicycling network. Less well-known is the substantial effort Davis has made to avert the kind of sprawl found in most US cities. Multi-family housing is distributed throughout the city, neighborhood shopping centers are within a short bike ride for most residents, and the city has improved sidewalks, landscaping, and public spaces to promote its traditional downtown. Davis restricts development beyond the current urban boundary while at the same time encouraging infill development within the boundary. As a result, Davis is the sixth densest urbanized area in the US and an exemplar of what small cities can achieve with coordinated policies and careful planning.

Consequently, when the Target Corporation proposed opening a store in Davis in the mid-2000s, a fiery debate erupted. At the time, the city's General Plan deemed "warehouse style retailers ... inappropriate given the nature and scale of the Davis market" and restricted retail businesses outside downtown to sizes appropriate for serving small neighborhoods rather than larger regions. The land use code limited store sizes to 30,000 square feet, far less than the proposed 137,000 for the Target store. Though the City Council approved the project in June 2006, it recognized the decision's combustibility and held a public referendum on the development agreement.

Impassioned Davis residents voiced concerns regarding Target's arrival, including its environmental, economic, fiscal, social, and cultural impacts. Some residents feared that Target would harm local businesses and draw shoppers away from neighborhood centers. Others argued that allowing Target to move into Davis would be a public endorsement of big-box retail, a type of built form thought to be incompatible with the city's larger sustainability goals and town culture. By contrast, supporters of the project argued that Davis residents already shopped at stores like Target in other cities, and that a Davis Target would fill a retail need, keep sales tax revenues within the city, and reduce driving. In November 2006, 51.5 percent of voters cast their ballots in support of the project, and a Target store finally opened in Davis in October 2009. >

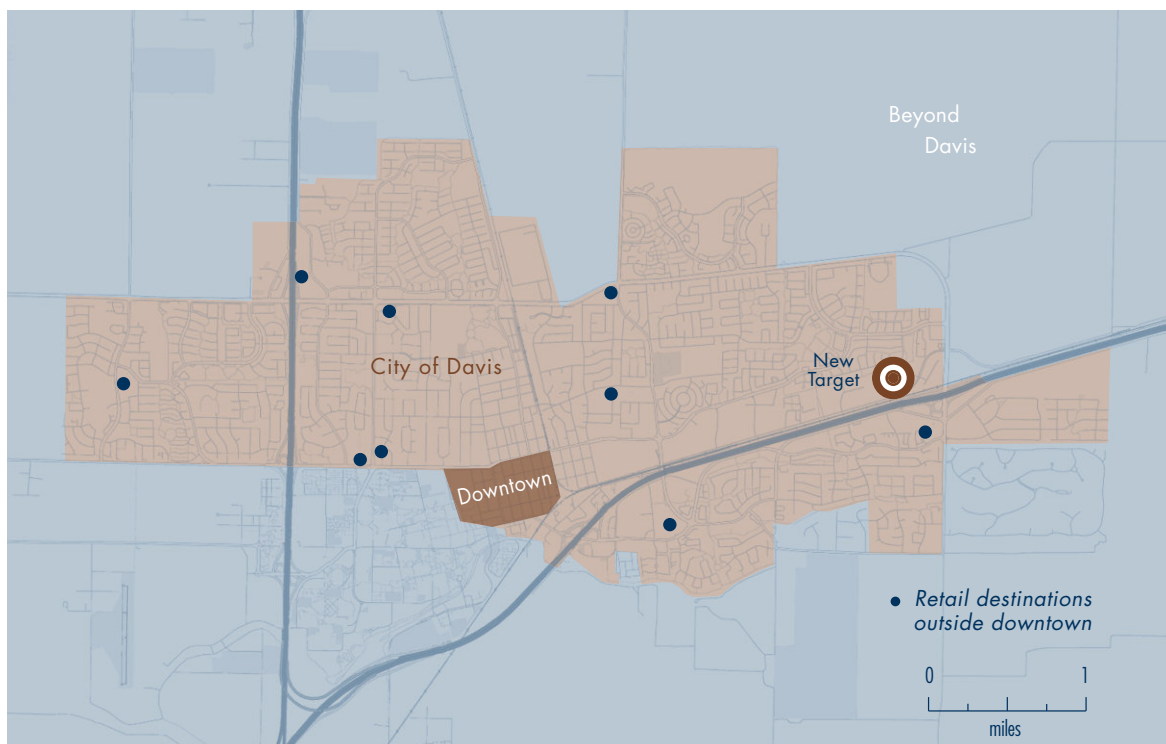
Impassioned Davis residents voiced concerns regarding Target's arrival, including its environmental, economic, fiscal, social, and cultural impacts.

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FIGURE 1

**Retail Locations
in Davis**



MEASURING THE CHANGES

Davis is not the first community to debate the desirability of big-box retail. Around the US, communities have adopted policies to restrict stores like Target and Walmart, which are believed to threaten local businesses, offer low-wage jobs with limited benefits, and harm the environment. The opening of the Target store in Davis—the first big-box retailer in the city—gave us a perfect opportunity to test these assumptions. We focused on the two questions most debated in Davis. First, how did Target change residents' total vehicle travel and greenhouse gas emissions? And second, how did Target affect downtown businesses?

To measure how Target affected Davis, we surveyed residents about their shopping behavior: once just before the opening of the store, and once a year after its opening. In total, 1,018 residents completed the online survey in 2009, and another 1,025 residents did so for the survey in 2010. In analyzing the data, we excluded respondents under age 25 in order to leave out most UC Davis students, whose shopping habits likely differ from those of the general population.

The survey included questions about the frequency and travel mode for trips to different shopping destinations: stores in downtown Davis, other stores in Davis, stores outside of Davis, and, in the second survey, the Target store in Davis. The survey also included questions about online shopping. We asked respondents to focus on shopping for 17 categories of items found at Target other than groceries. For the most recent trip to each destination, respondents reported what kinds of items they purchased and how much they spent. In addition, we asked respondents to give us an intersection near their home so that we could calculate distances to each of the different shopping destinations. We then pieced this information together to estimate the effects of Target's opening.

VEHICLE MILES TRAVELED

How did the Target store’s opening affect vehicle travel and greenhouse gas (GHG) emissions? We estimated the change in VMT for the population as a whole by looking at how often residents shop at different destinations, what modes they used to get there, and whether they stopped there on their way to or from other places.

We estimate that, after Target opened, average monthly shopping VMT declined from 98.4 to 79.5 per person, a drop of nearly 19 miles per month per adult age 25 or over. This decline translates into a savings of over 7.5 million VMT per year, reducing CO₂ emissions by 2,0 metric tons, equivalent to the total CO₂ emissions from 589 passenger cars for a year.

We found that shopping trips shifted in significant ways after the Target opened. Over 90 percent of respondents shopped at least once at Target during its first year, and the average shopper visited 2.1 times per month. As one would expect, trips to other destinations dropped (Figure 2): a small drop in trips to downtown (from 3.3 to 3.0 trips per month), a larger drop to stores outside downtown (from 4.3 to 3.4 trips per month), and the largest drop to stores outside Davis (from 3.5 to 2.5 trips per month). Although total shopping trips declined from 10.3 to 9.5 trips per month, total shopping occasions, including online shopping, stayed relatively stable at around 14 occasions per month.

The geography of local retail was a big factor in changes in vehicle travel and greenhouse gas emissions. On average, respondents live 2.2 miles from downtown, 2.0 miles from other stores in Davis (which are dispersed throughout town), and 3.5 miles from Target (located at the eastern edge of town). Davis is separated from neighboring cities by a wide band of agricultural land, which means that the stores where residents shop outside Davis are on average 18 miles away. Thus, every trip to Target that replaced a trip to a store outside of Davis produced an average of about 15 fewer vehicle miles >

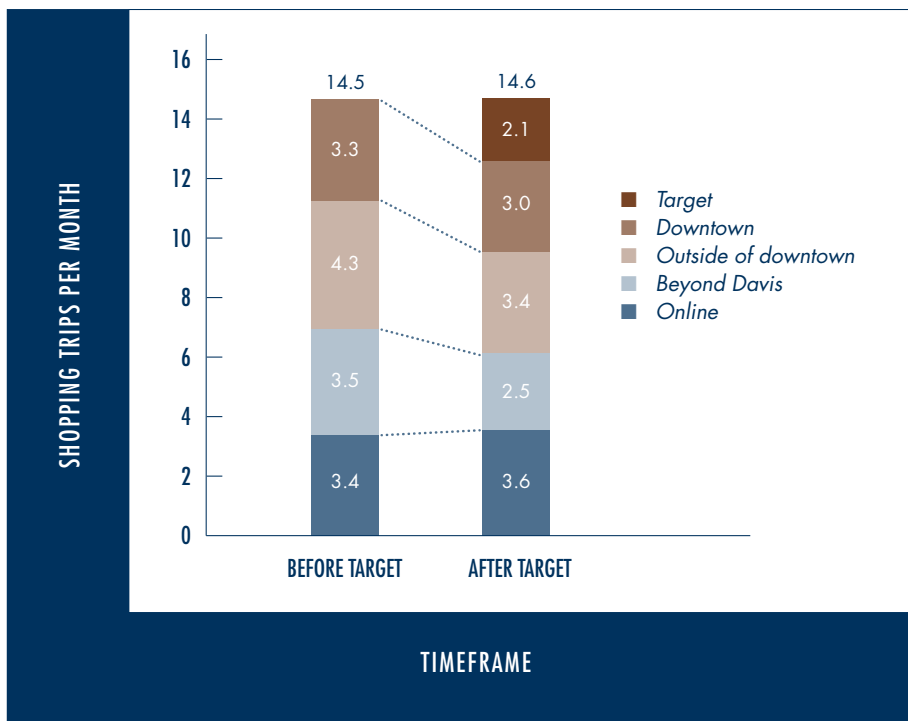


FIGURE 2
Monthly Shopping Trips to Each Location

traveled. The savings were even greater if the trip to Target was “on the way somewhere else,” which was rarely the case for trips to stores outside Davis.

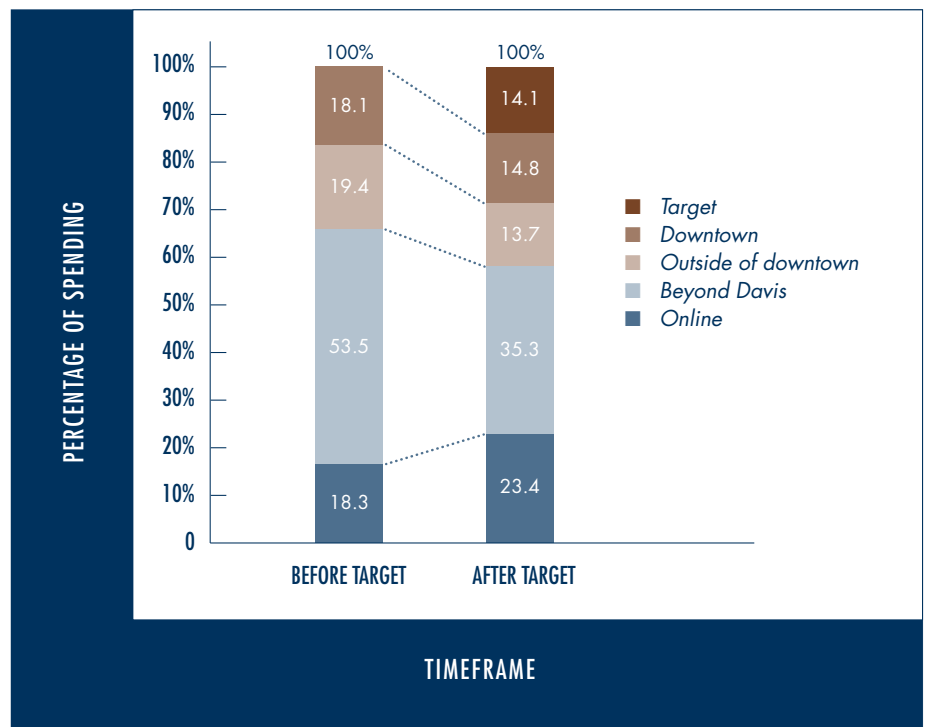
Nearly all trips to stores outside Davis were by car, but within Davis, close to 20 percent of respondents walked, bicycled, or used transit. So when residents shifted from stores outside of Davis to Target in Davis, they were more likely to get there by means other than driving, which also reduced VMT.

EFFECTS ON DOWNTOWN

How did Target affect downtown businesses? Did the reductions in VMT and GHG emissions come at the expense of downtown? Residents shopped downtown somewhat less often after Target opened. On the other hand, residents made many fewer trips to stores outside downtown Davis, where businesses are more likely to be national chains. Thus, while Target’s arrival coincided with a drop in total trips, chain stores were affected more than locally owned stores.

Changes in expenditures on Target-type items mirror the changes in trip frequency. Before Target opened, we estimate that residents had close to \$950 per month in total consumer expenditures. They spent about half of this amount at stores outside Davis and just under 20 percent both at downtown stores and at stores in other areas of Davis (Figure 3). After Target opened, overall spending stayed about the same, but spending at Target averaged \$128 per month, or about 14 percent of spending. The share of spending outside Davis dropped from one half to just over one-third of overall spending, while the share at Davis stores outside downtown dropped from about 20 to 14 percent. The share of spending in downtown also dropped but less than the share of spending in these other destinations, from 20 percent to 15 percent.

FIGURE 3
Percent of Monthly Spending in Each Location



Other results from the survey suggest that downtown shopping is simply different from shopping at Target or elsewhere. Residents shopping downtown are more likely to browse rather than buy and are more likely to shop at locally owned businesses. A series of survey questions on perceptions show that Davis residents see downtown stores as offering higher priced but higher quality products, with a more limited product selection. These stores, residents say, offer more interaction with customers compared with stores elsewhere, but returning items is more difficult and the hours of operation are more limited. Downtown is easier to reach by walking or biking than Target is, but residents find it harder to drive or park there. The only characteristics on which downtown did not differ from Target were the quality and availability of bike parking, rated by residents as high in both locations (this *is* Davis). Not surprisingly, given the mix of stores downtown, most shopping trips for Target-type items were not to downtown even before Target opened. In other words, Target is not a good substitute for downtown shopping.

LESSONS FOR OTHER CITIES

Davis isn't like most other American cities. Before Target opened in the city, the nearest Target or Walmart was at least eight miles from the center of Davis, a result of aggressive growth management policies that have preserved the agricultural lands separating Davis from neighboring cities. When Target opened, the average driving time to the nearest big-box store fell by two-thirds. In other cities, the nearest big-box store is probably much closer, and the opening of a new store may not reduce the distance very much. Nonetheless, any reduction in distance to the nearest store could reduce miles driven as long as residents don't shop more often as a result.

Before Target opened, stores in downtown Davis did well in the absence of big-box stores. As a result of their initial vitality, stores in downtown Davis may have been more immune to the Target shock than downtown stores of other communities. On the other hand, many downtowns have already been decimated by the proliferation of chain stores and strip malls to the point where one more big-box store would have little impact. For both healthy downtowns that offer something different from big-box stores, and for struggling downtowns already affected by them, fears about another big-box store may be exaggerated.

Target did not mean the end of life as we know it in Davis. The store added to the shopping options available to residents, and it lowered overall greenhouse gas emissions without seriously harming downtown. The new Target is popular with Davis residents: while just over 50 percent of voters supported the Target store, nearly 90 percent of respondents reported having shopped there a year after its opening. And the share of respondents who agreed with the statement, "It was a good decision to allow a Target store in Davis," increased from 60 percent before its opening to 68 percent afterwards. Other communities, with the right combination of policies in place, might also find that big-box retail is not so bad. ♦

This article is adapted from "Measuring the Impacts of Local Land-Use Policies on Vehicle Miles of Travel: The Case of the First Big-Box Store in Davis, California," originally published in the *Journal of Transport and Land Use*.



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Informal Parking:

TURNING PROBLEMS INTO SOLUTIONS

DONALD SHOUP

Cities regulate almost every aspect of both on- and off-street parking, and they employ legions of parking enforcement officers to ensure that drivers obey these regulations. If so much parking is formal, regulated, and policed, what then is informal parking?

INFORMAL MARKETS FOR OFF-STREET PARKING

Informal parking markets operating outside the regulated system can fill a market niche that is hard to serve by formal means. They often appear near sites that generate short, sharp, infrequent increases in parking demand. Near the Los Angeles Coliseum, for example, residents charge for parking in their driveways on game days. Drivers may have to walk a few blocks to the stadium, but after the game they can leave from residential driveways much faster than from a crowded stadium lot where everyone is trying to exit at the same time. These dispersed informal lots also reduce the severe congestion caused by peak entry and exit queues.

The demand for game-day parking is so strong that some cities have legalized the informal markets. For example, Michigan Stadium in Ann Arbor is the largest sports arena in the US, drawing crowds of over 100,000 for every home game since 1975. The large stadium crowds have created an informal market for off-street parking. Ann Arbor prohibits parking on lawns, except on football game days. Residents park their own cars on the streets before the games to create off-street spaces on their lawns, driveways, and back yards. Many drivers think that paying for parking is un-American, but residents who receive the revenue know that paying for what you use is a traditional American value.

Donald Shoup is Editor of ACCESS and Distinguished Professor of Urban Planning in the Luskin School of Public Affairs at the University of California, Los Angeles (shoup@ucla.edu).



INFORMAL MARKETS FOR ON-STREET PARKING

In neighborhoods where curb parking is scarce but free, informal markets can be quite profitable. Apartment building doormen in expensive neighborhoods in New York and San Francisco, for example, have become successful parking entrepreneurs, using their buildings' taxi zones to park cars for visitors, and earning tips for their service. When a curb space opens up near the building, the doorman moves the visitor's car into it. If a resident who parks on the street then comes home and cannot find a curb space, the doorman moves the visitor's car back to the taxi zone to create a curb vacancy, the resident parks in it, and the doorman receives another tip.

Alternate-side parking regulations in New York City create another informal market. To allow for street cleaning, New York prohibits parking for a 90-minute period on one side of the street on Mondays, Wednesdays, and Fridays, and on the other side on Tuesdays, Thursdays, and Saturdays. During the 90 minutes when parking is prohibited on the side being cleaned, many residents double park their cars on the other side of the street. This alternate-side regulation creates an informal market controlled by doormen. Residents who park on the street give their car keys to their doormen, who charge a monthly fee to move the cars from one side of the street to the other. When drivers want to use their cars, they ask the doormen where their car is. Some doormen leave gaps of curb space in front of and behind each vehicle they park, but not enough of a gap for someone to park in it. Then, when the doorman needs to park another car, he simply moves the first car forward to create a second parking space. >



Informal markets for curb parking can also have a work requirement for the parkers. Residents of Boston and Chicago who have shoveled out a parking space after a snowstorm traditionally use lawn chairs or trash cans to claim it until they return. A Boston City Council member explained, “It’s a cultural thing. When people work hard to clean a spot, you want people to respect that. It’s part of living in a dense community.”

INFORMAL PARKING ON SIDEWALKS

Parking on sidewalks has evolved as an informal custom in some older neighborhoods in response to a shortage of free parking on the streets. I began to study this informal parking market when teaching a course on Urban Transportation Economics at UCLA. Many of the students live in North Westwood Village, a 15-block neighborhood next to campus. Drivers often park on the aprons of driveways (the paved area between the sidewalk and the street), with the front of the car extending over the sidewalk. Others park in the driveway with the back of the car extending over the sidewalk (and no part of the car on the apron). No matter how far the cars extend over the sidewalk from either the apron or the driveway, drivers call it apron parking. Landlords charge their tenants for the right to park in the aprons, usually about \$50 a month. This informal market for parking on sidewalks lets landlords charge for parking spaces they don’t own and shows that parked cars are more important than pedestrians.

Parking on a sidewalk violates both California and Los Angeles laws, but parking enforcement officers in the North Village ignore this violation because it is a student area and its city councilmember requested “relaxed enforcement.” The result is a good example of what George Kelling and James Wilson referred to as the “broken windows” theory of urban disorder:

Social psychologists and police officers tend to agree that if a window in a building is broken and is left unrepaired, all the rest of the windows will soon be broken...one unrepaired broken window is a signal that no one cares, and so breaking more windows costs nothing.

If we substitute cars parked on sidewalks for broken windows, North Westwood Village illustrates this theory. Where enforcement officers do not ticket the first cars parked on the sidewalk, more drivers will park on the sidewalk. Eventually, drivers will park on sidewalks throughout the neighborhood. Because the city has relaxed enforcement in North Westwood Village, an informal parking market has taken over the sidewalks.

My students began to study informal parking in the North Village, counting curb spaces and parked cars, analyzing census data, interviewing residents and property owners, and documenting the situation with photographs. The students counted 205 cars parked on the driveway aprons on a typical day. This might seem like a small number compared to the neighborhood’s 11,000 residents, but these 205 cars were enough to block the sidewalks on every street. A tiny minority inconveniences life for the vast majority.

THE AMERICANS WITH DISABILITIES ACT

Informal parking on sidewalks may seem to be only a local issue, but the US Supreme Court ruled in 2003 that the Americans with Disabilities Act (ADA) applies to sidewalks. The decision in *Barden v. Sacramento* requires cities to make public sidewalks accessible



to people with disabilities. Because of this ruling, cities must remove barriers that block access to sidewalks. This decision has created a serious liability for cities like Los Angeles that have informally allowed drivers to park their cars on sidewalks.

Two ADA lawsuits against Los Angeles have spurred reform. Both lawsuits address broken sidewalks and cars parked on the sidewalks. After years of neglect, these lawsuits have forced the city to reconsider the informal policy of relaxed enforcement and to decide exactly what should be legal and what should not. Given the threat of ADA lawsuits over inaccessible sidewalks, all cities that informally allow illegal parking on sidewalks will need to find ways to mitigate the withdrawal pains caused by enforcing the law.

EASING THE PATH TO FORMALITY

The loss of informal apron parking will increase the already high demand for curb parking, but Overnight Parking Permits can help solve the problem. Like many other cities, Los Angeles allows the residents of any neighborhood to adopt an Overnight Parking Permit District that prohibits overnight on-street parking except by permit holders. Enforcement officers need to make only one visit during a night to cite all cars parked without permits. Los Angeles charges residents \$15 per year (less than half a cent per day) for each permit in an Overnight Parking Permit District. Residents can also buy guest permits for \$1 per night. >

Most people want sustainable cities, good public transportation, walkable neighborhoods, public safety, and less traffic. But they also want free parking, which undermines these other goals.

Given the high residential demand for on-street parking in North Westwood Village, the demand for overnight permits will greatly exceed the supply of on-street spaces. The city could keep the permit price low and limit the number of permits in some way, such as by a lottery. Alternatively, the city can charge a fair market price for the permits, so the number of permits demanded will equal the supply of on-street parking spaces.

Suppose the city charges North Village residents the same price for a parking permit that UCLA charges students for a parking permit in the nearby campus residence halls (\$96 a month). If the city charges \$96 a month (about \$3 a day) for 857 overnight permits (equal to the number of on-street parking spaces in the North Village), the new revenue to pay for public services will amount to about \$987,000 a year ($\$96 \times 12 \times 857$), or about \$66,000 a year for each of the 15 blocks in the North Village.

Paying for curb parking will never be politically popular, but it will make finding a curb space much easier. To increase the acceptability of this market-based solution, the city can spend the new parking revenue to improve public services in the North Village: to repair broken sidewalks, plant street trees, and fill potholes—all of which the North Village needs. Public safety is another issue. In 2012, North Westwood Village experienced three rapes, 15 robberies, 20 aggravated assaults, 58 burglaries, and 89 larceny thefts. Using some of the parking revenue to improve public safety can be far more valuable than providing free parking for a few cars.

Dedicating parking revenue to the neighborhood that generates it has built political support for priced parking in other cities. The public improvements financed by fair market prices for 857 curb spaces will improve life for the North Village's 11,000 residents, and can help to satisfy the city's obligation to make the sidewalks accessible.

THE SOUND OF CHANGE

Solving the problems created by parking on the sidewalks will create long-term economic and environmental benefits but also short-term political conflict. As Niccolò Machiavelli wrote in *The Prince* in 1532:

There is nothing more difficult to take in hand, or more uncertain in its success than to take the lead in the introduction of a new order of things. Because the innovator has for enemies all those who have done well under the old order of things, and lukewarm defenders in those who may do well under the new.

Or as Woodrow Wilson said almost 400 years later:

If you want to make enemies, try to change something.

Most people want sustainable cities, good public transportation, walkable neighborhoods, public safety, and less traffic. But they also want free parking, which undermines these other goals. Fortunately, few people will have to give up their car if the city enforces the law against parking on the sidewalks and creates a formal market for parking on the streets. Instead, a few car owners will decide that a neighborhood without ample free parking is not the best place to buy or rent an apartment. People who cannot afford or choose not to own a car will take their place. During the transition, all the whining will be the sound of change.



TURNING PROBLEMS INTO OPPORTUNITIES

Informal parking markets often respond to the failure of cities to create formal markets for on-street parking. Even on some of the most valuable land on Earth, cities offer free curb parking on a first-come, first-served basis. In dense neighborhoods, how could informal markets for this free parking not emerge?

If curb parking is free, entrepreneurs will find ways to create informal markets that serve drivers who are willing to pay for convenience. These informal markets respond to the problems caused almost entirely by free curb parking. The shortage of free curb parking is not merely a problem, however. It is also an opportunity to create a formal market with fair prices that efficiently allocate land for parking. A formal market for on-street parking will reduce traffic congestion, air pollution, and greenhouse gas emissions, and will generate ample revenue to pay for neighborhood public services.

Fair market prices can end the Hundred Years' War over free curb parking, and the revenue will provide a peace dividend to rebuild our neglected public infrastructure. Livable, walkable cities are worth far more than free parking on the streets and sidewalks. ♦

This article is adapted from "Informal Parking Markets: Turning Problems into Solutions," originally published in the book, *The Informal American City*.

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SUBURBAN TRANSIT IN MEXICO CITY

ERICK GUERRA

Over the past decade, governments and development agencies have invested significantly in high-capacity transit in Asian, Latin American, and African cities. Beijing's subway system grew from just two lines in 2000 to one of the world's largest metro systems today. Each year, a dozen new Bus Rapid Transit (BRT) lines open in cities around the world. Concerns about economic competitiveness, congestion, sprawl, pollution, and accessibility for the poor and middle class motivate these investments.

Despite increased high-capacity transit investment in many developing-world cities, little research has evaluated its effects on land use or travel behavior, particularly in fast-growing suburban neighborhoods. Yet the effects of transit investments almost certainly vary in areas with different spatial patterns, land use regulations, travel habits, and income levels. Most existing studies are either descriptive or recommend a specific technology—generally BRT—based on costs and passenger volumes. Several studies focus on factors that influence households' mode choice on existing systems, and the relationship between proximity to transit and land values.

As in other metropolitan areas, Mexico City's population has grown primarily in suburban neighborhoods, far from metro or BRT stations. Despite limited transit service, Mexico City's suburban residents use transit for a higher share of trips than central city residents. Suburban households rely on a combination of privately owned and operated minivans and minibuses and publicly owned metro and buses. When Mexico City Metro's Line B opened in 1999, it significantly expanded high-capacity transit into the large and densely populated suburban municipality of Ecatepec. The investment appears to have increased population density around suburban stations with limited or no influence on downtown development or regional growth patterns, and improved transit service for local residents with limited or no effect on congestion or car ownership.

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HOW TRANSIT INVESTMENTS INFLUENCE TRAVEL BEHAVIOR AND LAND USE

The effects of transit projects depend on the cities and neighborhoods where they are built. Dense, diverse areas with pedestrian-friendly designs tend to bolster transit ridership by increasing the speed, convenience, and reliability of transit relative to driving. Due to income constraints or personal preference, transit users may live in dense, diverse, transit-friendly areas. Dense concentrations of people and jobs promote high transit use due in part to an increase in the total number of origins and destinations in a transit system's catchment area. Below a certain density threshold, neither land use changes nor transit investments are likely to influence ridership. In many developing-world cities, even the most peripheral neighborhoods often surpass these minimum density thresholds. Mexico City's suburban neighborhoods have an average density of 60 people per acre, well above threshold densities established in the United States for even the highest-capacity, heavy-rail systems.

High-capacity transit has the largest influence in places where real estate markets are strong, government regulations and financing are supportive, and the accessibility benefits of new service are high. In the United States and Europe, these conditions are most prevalent in downtown areas. However, even in dense, centralized regions with rail systems and strong real estate markets, jobs and populations have grown more quickly away from transit stations than around them. Thus, while transit has increased centralized development, it has not necessarily prevented decentralized development.

In Mexico City and many other parts of the world, real estate markets, land use, and regulations are somewhat different than in the US and Europe. Several academics have >

argued that high-capacity transit investment increases downtown development and commercial activity in developing-world cities. Suburban impacts, however, may be at least as important. Suburban neighborhoods tend to have strong, informal real estate markets (particularly for housing), light and weakly enforced land use regulations, and high transit use. This suggests that transit investments may bring large accessibility benefits and produce significant land use changes in suburban neighborhoods. Furthermore, the white-collar workers associated with downtown commercial developments in Mexico City rarely use transit. As such, transit investments are unlikely to spark significant commercial office developments.

LAND USE AND TRANSIT IN MEXICO CITY

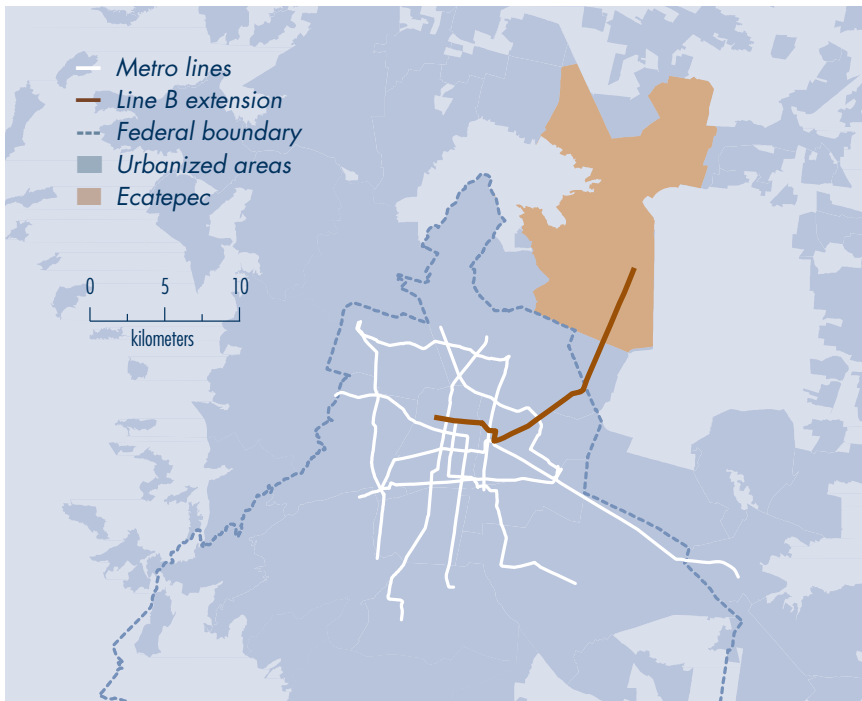
Mexico City's metropolitan residents live in dense neighborhoods (67 people per acre on average) that rely on transit for almost two-thirds of all trips (excluding pedestrian trips). In this sense, Mexico City exhibits the most commonly referenced and strongest aspect of the transit and land use connection: high densities support high transit use. The transit system consists primarily of a 225-kilometer metro network that provides high-capacity service in the city proper, and a diffuse network of *colectivos*—privately

owned and operated minivans (*combis*) and minibuses (*micros*)—that provide feeder and local service throughout the metropolis. On an average day in 2007, 52 percent of all vehicular trips relied on *colectivos* for at least part of the journey, while 32 percent of trips relied exclusively on this mode.

Although Mexico City's metro system is centrally located, most transit riders are not. Since the first 13-kilometers of the metro opened in 1969, most population growth has been in areas without metro service. Only 11 of the current 192 metro stations are located outside of the Federal District of Mexico City, an area that accounted for just 17.5 percent metropolitan population growth between 1970 and 2010. By 2010, 56 percent of metropolitan residents lived in the surrounding states of Mexico and Hidalgo. Nevertheless suburban residents rely on transit for a greater

share of trips than those living in the Federal District—65 percent compared to 60 percent. Suburban residents are particularly reliant on *colectivos*, but also use the metro with similar frequency (18 percent) compared to residents of the Federal District (19 percent). As a result of high suburban ridership, average daily boardings are particularly high at end-of-the-line stations. More than two-thirds of all metropolitan trips on the metro connected to a *colectivo*. Another 14 percent of metro trips linked to public buses, light rail, and other vehicular modes. Just 3 percent of metropolitan trips relied exclusively on walking and the metro.

FIGURE 1
Metro Lines in Mexico City



EXPANDING THE METRO INTO THE SUBURBS

Despite rapid peripheral development and high suburban transit use, the government has only recently begun to invest in suburban high-capacity transit. Of the eleven metro stations in the State of Mexico, eight are on Line B, which provides metro service into the northeast. The 24-kilometer Line B opened in two phases, in 1999 and 2000, and cost \$1.3 billion in 2013 US dollars. The line runs underground from east to west along the northern half of the center of the Federal District before emerging and running northeast into Ecatepec along the *Avenida Central*. As in many suburban municipalities, Ecatepec's residents are poorer, have lower car ownership rates, and live in more densely populated neighborhoods than the metropolitan average. And like in many other suburban areas, Ecatepec's population has grown rapidly over the past four decades.

As one of the earliest of Mexico City's few suburban high-capacity transit investments, the Line B extension can shed light on the likely effects of future suburban transit expansions. After a period of modest decline from 1994 to 1999, aggregate annual boardings appear to increase as a result of the opening of Line B (Figure 2). However, it is extremely difficult, if not impossible, to disentangle the effects of Line B on aggregate annual metro boardings from other shocks, such as the 1994 devaluation of the Mexican peso and ensuing economic crisis, or the more than doubling of metro fares from 40 centavos to 1 peso in December 1995. Furthermore, many of the riders who now board at Line B stations would still be riding the metro in the absence of Line B, but boarding at different stations. To account for these larger trends, this study examines land use and travel behavior around stations before and after the investment and compares them to five separate control areas. >

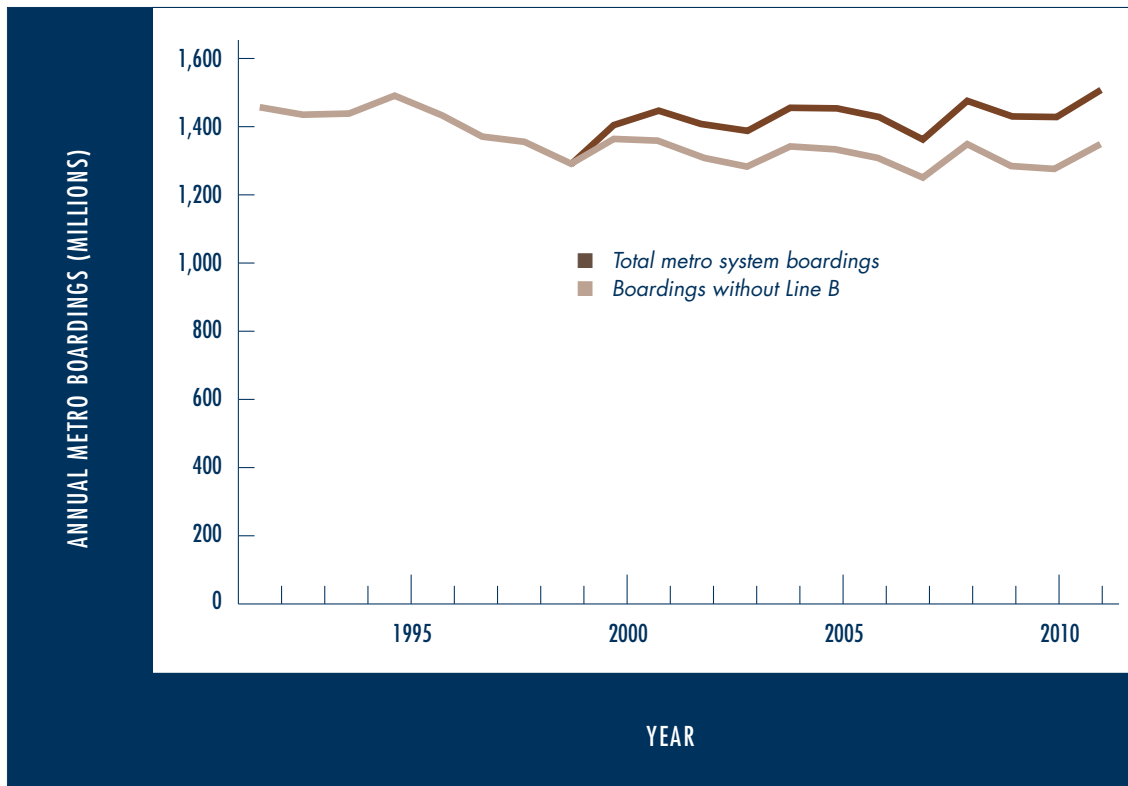


FIGURE 2

Metro System Annual Boardings



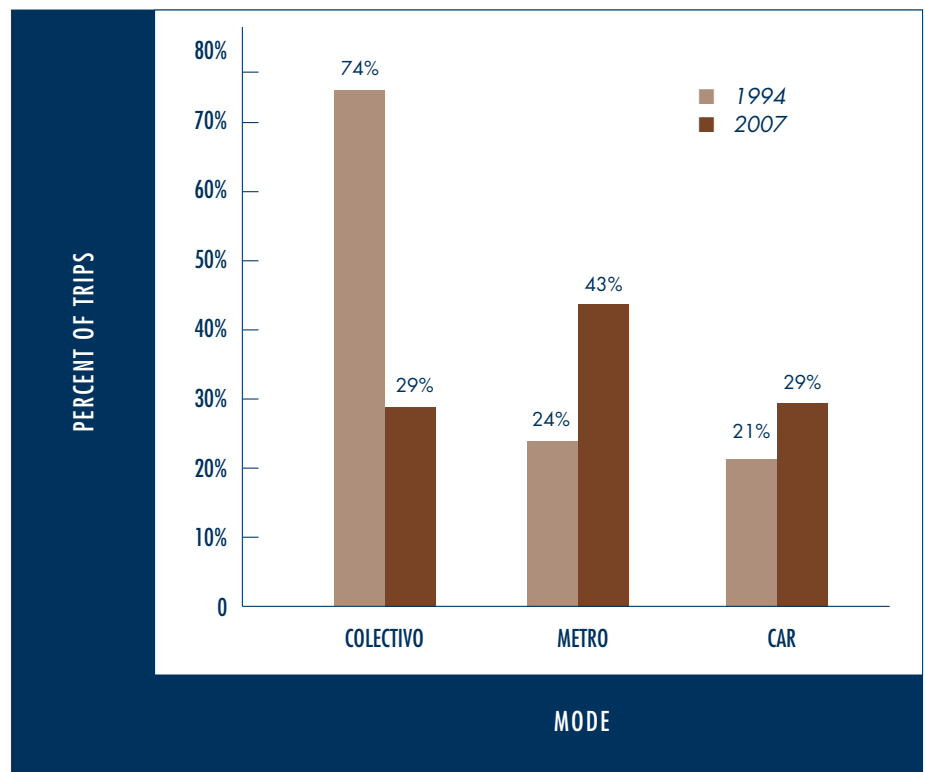
CHANGES IN TRAVEL BEHAVIOR NEAR AND AWAY FROM LINE B STATIONS

Line B reduced average travel times and expenditures on public transportation for nearby households and throughout Ecatepec. Residents living within a kilometer of stations in 2007 saved an average of 1.5 minutes and 2 pesos per transit trip (including those that did not use the metro) relative to 1994. By contrast, travel times and prices increased in the control geographies. These savings came primarily from households making trips to central locations in the metropolis. Lower costs and faster speeds have encouraged a significant increase in metro use. Residents within a kilometer of Line B's stations were nearly twice as likely to use the metro on a given trip in 2007 as in 1994. Compared to an average metropolitan resident, they were more than twice as likely to use the metro in 2007 and eight times more likely to rely exclusively on the metro. The share of trips by all residents of Ecatepec using the metro increased a more modest 11 percent.

The increased metro use has primarily come from former *colectivo* riders. Figure 3 shows the share of trips by households living within a kilometer of Line B stations that used a *colectivo*, the metro, or a car in 1994 and 2007. Although *colectivo* mode share declined throughout the metropolis, the decrease was notably stronger around Line B stations than in the control areas. Car use also increased throughout the metropolis, including around Line B and throughout Ecatepec. If Line B affected car use at all, it marginally constrained its growth in a localized area of a municipality where car use has been rising rapidly. (The automobile mode share increased by 38 percent around Line B, compared to 50 percent in Ecatepec.) While transit travel speeds increased for residents near Line B, travel speeds for other modes declined even more quickly around Line B than in other areas. This is likely related to fast-growing congestion and car use along the *Avenida Central*, an important northeast corridor for cars as well as the metro.

FIGURE 3

Trip Mode Shares around Suburban Line B Stations before and after Opening (Some Trips Use More than One Mode)



CHANGES IN URBAN FORM

By increasing the number of stations in the suburbs, Line B's construction quintupled the proportion of residents of the State of Mexico living near the metro. Nevertheless, a smaller proportion of all metropolitan residents lived close to metro stations in 2007 than in 1994, due to decreasing station-area densities in the Federal District and rapid growth in the most peripheral municipalities. Population density increased by 17 percent around Line B, but decreased by 11 percent around all stations. In sum, Line B appears to have significant local effects, but these are modest in relation to overall trends in settlement patterns. Mexico City has grown much more rapidly away from metro stations than around them.

Line B's influence on trip destinations, and thus its likely impact on central urban form, is less pronounced than its relationship with residential density. In general, the proportion of all trips, including work trips, to the urban center decreased from 1994 to 2007. This decline has been less pronounced around Line B, where the proportion of work trips to the center actually increased. Nevertheless, if Line B has influenced central commercial development, the effect has been small and difficult to measure. The most notable commercial office growth has been in the notoriously transit inaccessible Santa Fe neighborhood.

CONCLUSION

The Line B experience suggests that suburban metro extensions do not substantially reduce congestion, but succeed in improving travel for low and moderate income households. Suburban transit investments will likely concentrate housing development and encourage a shift from informal to formal transit in the immediate vicinity. But these investments will do little to change overall development patterns or reduce private car use. Since high-capacity transit creates less congestion, less pollution, and fewer collisions per trip than informal public transportation, a shift from informal transit to the metro may have additional public benefits. Perhaps most importantly, the metro provides high-quality service during peak hours, when congestion significantly reduces travel speeds for other modes. Suburban expansion also appears to be an effective way to maintain and increase metro mode share. Like Ecatepec, many suburban municipalities have lower household incomes and car ownership rates than the metropolitan average. These municipalities are becoming more densely populated over time and continue to absorb most metropolitan growth.

Despite the promise of higher ridership, expanding high-capacity transit into the suburbs faces several challenges. First, providing similar metro coverage per capita in the State of Mexico as in the Federal District would require at least 230 additional kilometers of metro. Given lower population densities in the most peripheral neighborhoods, more track and stations would be needed for equivalent service. At the same cost per kilometer of Line B, that would amount to \$12.4 billion in 2013 US dollars. Second, only new trips generate new revenue, given the flat fare system. In Ecatepec, 24 percent of trips already used the metro in 1994. In 2007, this figure increased to 27 percent. Even residents of the most remote municipalities, well outside of the metro service coverage, used the metro during 14 percent of weekday trips in 2007. Each new suburban investment reduces the overall ratio of fare revenue to capital and operating costs, and raises total costs. As a result, systematic attempts to increase metro coverage will require changes to fare policy or greater subsidies. ♦

This article is adapted from "Mexico City's Suburban Land Use and Transit Connection: The Effects of the Line B Metro Expansion," originally published in *Transport Policy*.

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A Bathtub Model of Downtown Traffic Congestion

RICHARD ARNOTT

William Vickrey is the “father of congestion pricing” and a Nobel Laureate in economics. While watching the ebb and flow of traffic from his Manhattan office, he developed a hypothesis that the dynamics of rush-hour traffic have the same properties as water flowing into and out of a hypothetical bathtub.

The Vickrey bathtub corresponds to Manhattan, water flowing into the bathtub corresponds to vehicles entering the traffic stream, and water draining out of the tub corresponds to vehicles exiting the stream. The height of water in the tub represents traffic density. The rate at which water drains increases with the height of the water until it reaches a critical height. Above that height, the outflow decreases as shown in Figure 1. Thus, the rate at which the bathtub drains reaches a maximum at the critical height. This critical height corresponds to the density of downtown traffic at which traffic jams start to become common. Above this level, traffic jams become more severe and the exit stream slows. >

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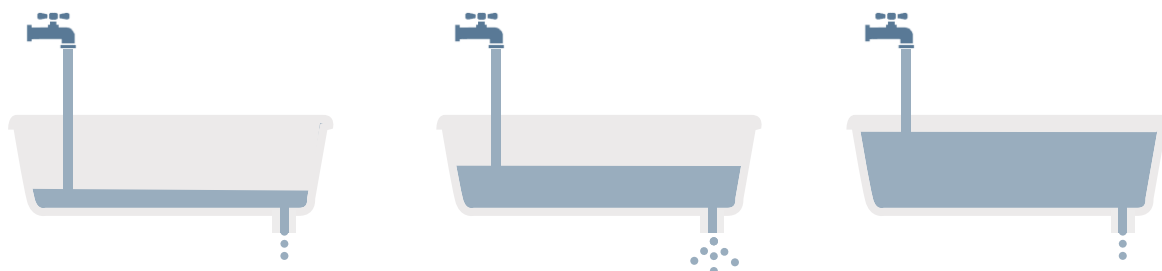


FIGURE 1
The Vickrey Bathtub

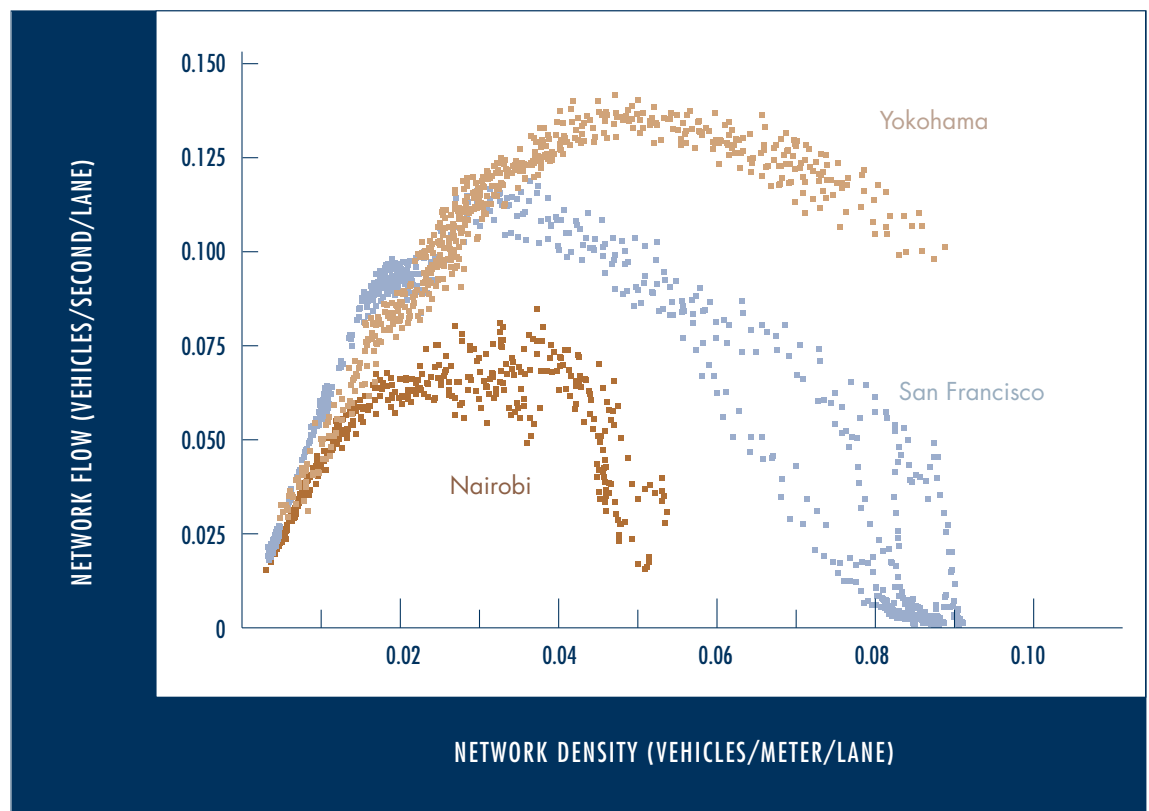


A similar phenomenon occurs in electricity distribution networks. In the context of electricity distribution, overloading the system results in brownouts and eventually blackouts. In the context of downtown traffic congestion, overloading the system results in traffic jams and eventually gridlock.

Vickrey based his hypothesis on traffic flow theory and careful observation, since there were no data on the properties of traffic flow and density for an entire downtown area a quarter century ago. In this article, I review recent empirical work that supports Vickrey's hypothesis, I report on my own work developing a formal model of the Vickrey bathtub, and I discuss how the hypothesis provides insight into managing downtown traffic congestion through pricing.

Recent work by Carlos Daganzo and his students at UC Berkeley shows a predictable relationship between traffic flow and traffic density at the scale of a downtown area. They refer to this relationship as the area's *macroscopic fundamental diagram* (MFD). Figure 2 shows the MFDs for three cities around the world. Each dot corresponds to an observation. Observations were made at regular intervals throughout the business day and over days of the workweek. The observations document two important empirical regularities. First, under heavily congested conditions, traffic flow falls markedly as traffic density increases (which corresponds to the bathtub draining more slowly at high water levels). Second, the ratio of the outflow from the traffic stream to traffic flow is approximately constant (which corresponds to the bathtub draining at a rate that is tightly related to the height of water in the bathtub). Together, these two empirical regularities show that the Vickrey bathtub describes well how congested traffic behaves at the level of a downtown area. Other researchers have since confirmed these results for other cities.

FIGURE 2
Macroscopic
Fundamental Diagram
of Downtown Traffic
Congestion



Source: Gonzales, Chavis, Li, and Daganzo, 2011

PHYSICS OF TRAFFIC CONGESTION

Macroscopic models of traffic flow examine the relationship between the flow, density, and speed of traffic. In contrast, microscopic models focus on the behavior of individual vehicles.

In 1935 Bruce Greenshields reported on observations he made of the speed and traffic density of cars along a section of highway. He found that speed falls linearly with increasing density, from a maximum speed at zero density to complete gridlock at jam density. This finding is now referred to as Greenshields' Relation.

Combining Greenshields' Relation with the fact that flow is the product of density and speed generates the MFD displayed in Figure 3. The maximum flow—known as *capacity flow* or simply *capacity*—occurs at an intermediate density, known as *capacity density*. Travel on the upward-sloping portion of the MFD, labeled “congested flow,” corresponds to normal congestion, where flow increases with density. Flow decreases with increasing density on the downward-sloping portion of the macroscopic diagram, labeled “hypercongested flow.”

The installation of the first loop detectors on freeways in the early 1980s generated an abundance of data, which spawned considerably more sophisticated models of freeway traffic flow. However, until the very recent work reported above, no comparable data had been collected at the scale of a downtown area, and little comparable modeling had been done for downtown traffic. To simplify my model, I assume that Greenshields' Relation holds for downtown traffic. I also assume that the rate at which traffic exits the traffic stream is proportional to traffic flow. Together, these assumptions result in a model whose physics is analogous to that of the Vickrey bathtub. >

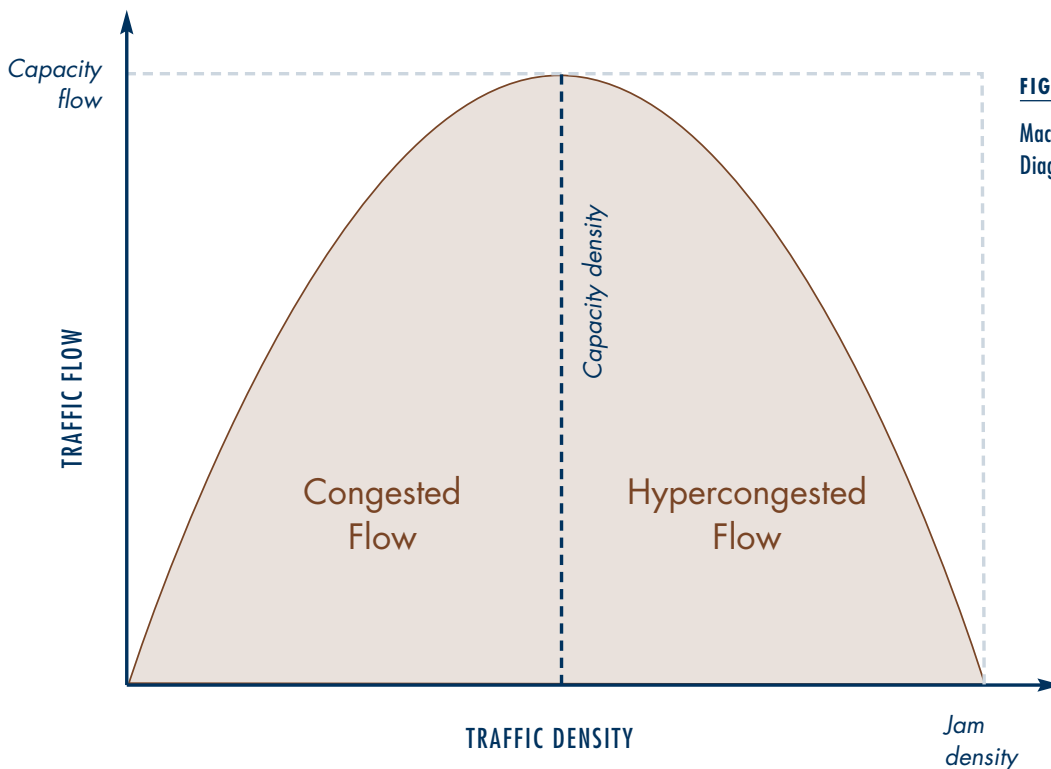


FIGURE 3
Macroscopic Fundamental Diagram

ECONOMICS OF RUSH-HOUR TRAFFIC CONGESTION

Consider a situation in which a fixed number of commuters travel from home to work over the morning rush hour. Each commuter has the same work start time and travels the same distance over city streets from home to work. Since it is physically impossible for all commuters to arrive at work exactly on time, some arrive early and others arrive late, experiencing costly schedule delay. Commuters arriving exactly on time experience no schedule delay but a large *travel time cost* since they travel when traffic is most congested. In contrast, commuters departing at the beginning of the rush hour experience little congestion and therefore shorter travel times, but they arrive at work considerably before their work start time, experiencing high *schedule delay cost*. The *private cost* incurred by a particular commuter equals her travel time cost plus her schedule delay cost. A commuter's *trip price* equals her private cost plus the congestion toll she pays, if a toll is in place. A commuter imposes an *external cost* on other travelers by adding to congestion and slowing other commuters down. The *social cost* of a trip is the increase in total trip costs the trip causes, and equals the private cost incurred by the commuter plus the external cost the trip imposes on others.

I compare the model's optimum morning rush-hour traffic dynamics, which can be achieved through ideal congestion pricing, with its no-toll equilibrium rush-hour traffic dynamics. *Equilibrium* is achieved when no commuter can reduce her trip price by altering her departure time. The optimum time pattern of departures minimizes total trip costs. Since transferring a commuter from a departure time with a higher social cost (private cost plus external cost) to a departure time with a lower social cost would reduce total trip costs, the optimum is achieved by equalizing the social cost of trips at different departure times. In contrast, the no-toll equilibrium time pattern of departure equalizes the private cost of trips at different departure times. Since the external cost of a trip at the peak of the rush hour is higher than one in the shoulders of the rush hour, the no-toll equilibrium pattern of departures entails excessive travel at the peak of the rush hour, causing the street system to become overloaded.

TABLE 1
Terminology

Travel Time Cost	The cost of the time it takes a commuter to get to work
Schedule Delay Cost	The cost to a commuter of arriving at work early or late
External Cost	The cost imposed by the commuter on other travelers by adding to congestion and slowing them down
Private Cost	Travel Time Cost + Schedule Delay Cost
Trip Price	Private Cost + Congestion Toll (where applicable)
Social Cost	Private Cost + External Cost
Total Travel Time Cost	Sum of the travel time cost of all commuters
Total Schedule Delay Cost	Sum of the schedule delay cost of all commuters
Total Trip Cost	Total Travel Time Cost + Total Schedule Delay Cost
Equilibrium	When no commuter can reduce her trip price by altering her departure time



The optimum time pattern of departures minimizes the sum of total schedule delay cost and total travel time cost. Consider first how total schedule delay cost alone would be minimized. The fixed number of commuters traveling over the rush hour is analogous in the Vickrey bathtub to a fixed volume of water that passes through the tub. Initially the tap would be turned to maximum so that the water level rises as fast as possible, until it rises to the level at which outflow is maximized. The inflow would then be turned down so that it equals the outflow, which would keep the bathtub draining at the maximum rate. Finally, when the fixed volume of water has flowed into the tub, the tap would be turned off, leaving the remaining water to drain out. Total travel time cost, in contrast, would be minimized by having water enter the tub at a trickle, which would ensure that commuters experience virtually no traffic congestion. In the optimum scenario, the water level would never rise above the critical level where outflow is maximized.

In the no-toll equilibrium, in contrast, traffic density may exceed the flow-maximizing density over much of the morning rush hour. Demand relative to capacity is defined as the ratio of the actual flow to capacity flow. In the bathtub analogy, it is the time it would take for the fixed volume of water to drain at maximum outflow. The higher the demand is relative to capacity, the longer the rush hour. Suppose that demand is high relative to capacity, so that the rush hour lasts for a long time, causing the first commuter to experience a high schedule delay cost and thus a high trip price. In the no-toll equilibrium, the commuter who arrives at work on time experiences the same high trip price, only in the form of high travel time. If trip distance is short, this high travel time is possible >

In very congested cities optimal tolling would still benefit commuters even if the toll revenue were completely squandered!

only if this commuter's average speed is low, which requires that traffic density exceed capacity density over at least a portion of the rush hour.

Table 2 illustrates the no-toll equilibrium in a downtown area where demand is high relative to capacity. All commuters have a work start time of 9 am and commute 10 miles from home to work on the downtown road network. Free-flow travel speed is 20 mph. Consider two commuters. The first is the earliest to depart from home and therefore the earliest to arrive at work, while the second commuter departs later and arrives exactly on time. The first commuter's schedule delay cost is \$10 for each hour she arrives early. Both commuters have a common travel time cost of \$20 per hour. Demand is so high relative to capacity that the first commuter departs at 5:30 am. Traveling at close to the free-flow speed of 20 mph on the 10-mile journey to work takes slightly more than half an hour, so that she arrives at work almost three hours early. Her travel time cost is slightly above \$10, and her schedule delay cost is slightly below \$30, for a trip price of about \$40. In the no-toll equilibrium, the commuter who arrives exactly on time must experience the same trip price of \$40. Since this commuter experiences no schedule delay cost, the entire trip price must be travel time cost. Since travel time cost is \$20 per hour, the journey to work takes two hours, which implies an average speed of 5 mph, only one-quarter of free-flow speed. With the assumed congestion technology, depicted in Figure 3, this low speed corresponds to heavily jammed traffic, with traffic flow substantially below capacity.

In the optimum scenario the departure rate from home is such that traffic never becomes jammed, and commuters experience only normal congestion. These optimal conditions can be achieved by charging a time-varying congestion toll set so that each commuter pays for the external cost her trip imposes on others. Each commuter's trip price then equals the social cost of her trip. Since commuters respond to the toll by altering their departure times so that the equal trip-price condition (now including the toll) continues to be satisfied, the social cost of each trip is the same, which is the defining feature of the optimum scenario. In the example, total trip costs are so much lower when this toll is applied that, even though commuters must pay the toll, the trip price is lower than in the no-toll equilibrium. Thus, optimal tolling would still benefit commuters even if the toll revenue were completely squandered! The additional benefits from spending or redistributing toll revenue are icing on the cake.

TABLE 2
Illustration of No-Toll Equilibrium

	DEPARTURE TIME	TRAVEL SPEED	ARRIVAL TIME	TRAVEL TIME COST	SCHEDULE DELAY COST	TRIP PRICE
Early Commuter	5:30 am	20 mph	6:00 am	\$10 $\frac{1}{2}$ hr x \$20/hr	\$30 3 hrs x \$10/hr	\$40
On-Time Commuter	7:00 am	5 mph	9:00 am	\$40 2 hrs x \$20/hr	\$0	\$40

(Free-flow travel speed is 20 mph and trip distance is 10 miles. The travel time cost is \$20/hr and the time early cost is \$10/hr. The common work start time is 9:00 am.)



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Building on the insights of Vickrey, I have described a model of downtown traffic congestion over the morning rush hour. This model has the property that traffic flow falls as traffic density increases beyond a critical level where traffic jams start to develop. In most large metropolitan areas, traffic jamming is severe. By reducing the incidence and severity of traffic jams, congestion tolling can improve the flow of downtown traffic during rush hours and decrease the costs of traffic congestion to such an extent that commuters are made better off even if they receive no benefits from the toll revenues collected. The strong support of the model's properties provided by recent empirical studies of downtown traffic congestion strengthens the case for congestion tolling in practice. ♦

This article is adapted from "A Bathtub Model of Downtown Traffic Congestion," originally published in the *Journal of Urban Economics*.

Painting the Present, Imagining the Future

RICHARD WILLSON

I am a transportation researcher and a landscape painter, two activities that couldn't seem more different. But are they? Transportation models are an abstraction from reality. Painting, even representational painting, requires abstraction from an infinitely complex visual field. Both types of abstraction require decisions about what is in and what is excluded. So perhaps transportation research and painting have more in common than we might think. Furthermore, do transportation paintings provide insights that transportation research excludes?

The abstraction required for research creates a separation from the richness of individuals' thoughts, feelings, and internal narratives. If travel patterns evolved slowly, this might not be such a problem. But lately that is not the case: travel is being rapidly altered by changes in technology, environment, and culture. A deep, qualitative understanding of travel has never been more important.

As a painter, I spend a lot of time observing and rendering transportation facilities. The freeway views displayed in this article are studio paintings, as Caltrans would not close the freeway for my usual "en plein air" (open air) style. The subject is the iconic 110 Freeway in Southern California; the perspective is the visual field of the driver. When on display, the paintings evoke reactions that provide insights into how people feel about their travel. A typical response is that there is not *enough* traffic shown, which when stated, is usually followed by a wink that suggests I understand the grim reality of traffic. Viewers express a desire for speed but share their horror of those who drive too fast. They yearn for the "good old, uncongested days" but have a false picture of prior conditions. Reactions are also tied to experiences of the freeway in specific times and places such as being "almost home" or "past a bottleneck."

When I showed the paintings in South Pasadena—a small city whose residents are working to block the extension of the 710 Freeway—some viewers suggested that I didn't make the freeway ugly enough. They didn't want to acknowledge any pleasure in the freeway experience. "Are the paintings a celebration of freeways or an indictment?" "Are you [the artist] for or against freeways?" Contradictory emotions were on display: high expectations for personal mobility alongside unwillingness to accept local disruption.

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Hot Wheels. 2011. Richard Willson. Oil on canvas, original in full color, 30" x 24"

These complex tensions reveal the inadequacy of relying on economic data or simple attitudinal survey questions for transportation knowledge.

Creating the paintings has helped me understand three aesthetic forms that are part of the freeway experience.

First, the windshield of the vehicle frames an *aesthetic of the visual landscape*. The dimensions of the window frame replicate a movie screen or flat screen television. When driving, we create our own movie, complete with streaming visuals and an internal narration. While the world beyond the window is three dimensional, the frame suggests a two-dimensional world. In this way, the driving experience is a transition from the immersive experience of a person on foot, to the detached, two-dimensional experience of human-made virtual worlds. Drivers are separated from a three-dimensional reality by a glass curtain. They observe the beauty and ugliness of the city from a command position, protected from intrusions into their personal space. They are looking forward, down the road, with the agency that comes with control. This contrasts with the experience of >

transit riders, walkers, and cyclists, who are either looking out the side window of a transit vehicle or are engaged by the urban environment.

There is beauty in the infrastructure itself, of course, as seen in soaring freeway interchanges and ribbons of concrete reflective of the underlying topography. Drivers experience the power of human ingenuity. The desire for order is fulfilled in the networks, systems, hierarchy, and uninterrupted continuity of freeways. Freeways provide hard edges and boundaries that telegraph human organization of the natural environment. But they also show the sky, flora, and fauna that flow by in changing seasons. How many people have experienced an amazing sunset alone in their vehicle, and how did driving affect their perception of the scene?

Second, freeway travel evokes an *aesthetic of driving*. This is an essential part of the driver's experience, not available in other modes. Freeway driving means power: mastery of fire that overcomes inertia when mashing the gas pedal down. There is pleasure in acceleration and the masterful handling of the vehicle, sensing coefficients of friction, managing weight transfer, and finding the apex of a turn. And of course, a vehicle can be an instrument for dominating other drivers, cyclists, and pedestrians.

Third, freeway driving reveals an *aesthetic of cooperation*. While media attention focuses on driver discourtesy, competition, and road rage, clear-eyed observation of driver behavior reveals that cooperation and courtesy dominate the experience. Without enforcement present, drivers let others merge into their lanes, take turns merging, pull over to assist others, and move out of the passing lane if driving slowly. The freeway system could not function without this cooperation. Drivers participate in a dance, generating a communal choreography as they go. Of course there are exceptions, but courtesy and altruism rule the day.



Rush. 2010. Richard Willson, Oil on canvas, original in full color, 48" x 24"



Keyhole. 2011. Richard Willson, Oil on canvas, original in full color, 36" x 18"

The experience of painting these freeways taught me to observe carefully and avoid jumping to conclusions, just as I should in research. It made me think about the people in the vehicles, and wonder about their experience. While transportation facilities are fixed, their use depends on subjective human beings. More fundamentally, even though my research seeks to reduce automobile dependency, I became aware of how much appreciation and fondness for freeways I was bringing to the paintings—these wondrous but flawed human achievements.

I was painting a nostalgic farewell to a time never to return. The modernist vision of free flowing freeways is over. Communication replaces movement and the virtual challenges the real. Extreme congestion undoes the driver's feeling of control and agency. Technological driving assistance and autonomous vehicles undermine the idea of the driver as the commander of the enterprise. Electric vehicles eliminate the "mastery of fire" feeling. Many young adults have never experienced driving down a freeway, and they do not seek it. They don't own cars. They live in the three-dimensional world on foot, on bicycles, and in transit vehicles. Automakers know this—they are branching into mobility services. Application developers know this—they are developing services that render the reasons to own a personal vehicle moot. This is truly a sea change. Do transportation researchers know this?

Transportation paintings do not solve the research challenges of this new era. Neither do they overcome the distance between research and individual subjectivity. Painting transportation facilities does, however, invite me to observe and reflect. It makes me more open to understanding change. And if the paintings are doing their work, they lead viewers to consider the less tangible aspects of travel, and their own choices. ♦

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