Pricing and Parking Management to Reduce Vehicle Miles Travelled (VMT)

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Executive Summary

Background

A research preliminary investigation entitled "*Parking Utilization and Site Level Vehicle Miles Travelled (VMT) Database"*, was requested by Caltrans customer representative, Alyssa Begley of the Division of Transportation Planning. Ms. Begley is the Caltrans Senate Bill (SB) 743 program implementation manager.
SB 743 was signed in 2013, requiring a move away from vehicle delay and level of service (LOS) under California Environmental Quality Act (CEQA) transportation analysis. It requires the Governor's Office of Planning and Research (OPR) to identify new metrics for identifying and mitigating transportation impacts. More information on this endeavor can be found at this Caltrans website: http://www.dot.ca.gov/hq/tpp/sb743.html.

The goal of this preliminary investigation will be to support the development of policies that promote access, improve parking management, while reducing vehicles miles travelled (VMT). The deliverable for this preliminary investigation will be a collection of the best practices and reports on parking supply and utilization, overall parking management and its relationship to the reduction of vehicle miles traveled (VMT). A research panel of members consist of Caltrans, the cities of Los Angles, San Jose, San Francisco and San Diego. The panel would like to know what studies have been done on in this subject area to ensure that there will be no duplication of efforts already completed or currently underway.

Summary of Findings

Is there a direct relationship between parking prices and reducing vehicle miles travelled (VMT)? This literature search did not uncover reports that directly relate these two subjects, however increasing parking prices *may* lower VMT. The answer is that there is a combination of several related factors in reducing VMT, and parking pricing is just one.

What studies have been done on parking management and parking pricing that reduces vehicles miles travelled (VMT)? This literature search uncovered that there are other-related factors that would discourage someone to use their personal vehicle to drive to their urban, downtown destination, where parking is scarce. Susan Handy of ITS, UC Davis and Marlon Boarnet of Sol Price School of USC, in their 2017 white paper entitled "A Framework for Projecting the Potential Statewide Vehicles miles Traveled (VMT) Reduction from State-Level Strategies in California" mentions four general categories that focus on reducing demand for driving: Pricing, Infill Development, Transportation Investments (Bike/Ped, Transit, Highways) and Travel Demand Management Programs. The authors state that these strategies are likely to reduce VMT if promoted by state policy. A 2014 policy brief posted by the California Air Resources Board (ARB) by Susan Handy, Marion Boarnet and Steven Spears entitled "Impacts of Parking Pricing and Parking Management on Passenger Vehicles Use and Greenhouse Gas Emissions" mentions "increasing existing parking prices, or charging for parking that is currently offered for free, has the potential to reduce vehicle travel (as measured by vehicle miles traveled (VMT)) and encourage mode switching by increasing the cost of private vehicle trips. As a result, it may also have the potential to reduce greenhouse gas emissions".

High parking pricing in an urban area is just one facet of the factors to reduce vehicle miles travelled (VMT). The first obvious factor to consider is, does the person own an automobile and can he/she park it in their driveway where the trip originates? Are the trip's origin and destination in low or high density developed areas? Does smart growth policies help reduce VMT? Second, can the automobile owner afford to pay for higher parking at the trip destination, based on their income? And thirdly, what would dissuade someone from driving downtown and opting for transit instead? Would it be efficient, effective and low-cost transit options? Congestion? Parking demand management, based on time of use, availability or high parking prices? Time it takes the person to travel? Urban, high density versus suburban locations with ample parking? It is known that approximately 76% of people still opt to take their car instead of transit, as stated in the 2010-12 California Household Travel Survey (CHTS). (Unfortunately, the new CHTS, which includes household income and car ownership will not contain information on parking). Is there a direct relationship between parking prices and reducing VMT? If people make a choice to travel everywhere by car, then of course there will be more VMT per capita. The answer may be that there is a combination of several factors in reducing VMT, and parking pricing is just one.

Related Research and Resources

Dr. Chatman of UC Berkeley 2013 study entitled "*Does TOD need the T? On the Importance of Factors Other Than Rail Access"* found that the availability of on and off-street parking was the key determinate in auto ownership and car dependence, as well as being conveniently located nearby bus access. Car ownership was reduced by 44 percent when strong bus access converged with poor parking availability. But many Californians still prefer their car and will take it, if there's parking available at home and at their destination. So how can VMT be reduced? Urban parking pricing is one of the several factors, including travel demand, parking supply, efficient public transit, land use and polices - that all can be directly related to VMT, and possibly reducing it. Offsite parking may help, but the VMT may not be *reduced* if parking isn't in the direct path to the destination. In fact, it may *increase* VMT if a car owner has to drive farther to park and then walk or take another form of travel (carpool, bus) to his/her destination or if they opt to take Uber or Lyft. Dr. Chatman states that his papers on parking pricing "…don't look explicitly at VMT but they do show that unfortunately there was no evidence of greater carpooling from pricing increases (which would imply a VMT reduction), though there was a reduction in the total number of cars using paid spaces (they paid more for longer periods, which reduced total turnover of vehicles using the spaces). His papers "showed that parking pricing in cities was an important factor that influenced transit ridership which in turn we would expect to be associated with lower VMT."

Gaps in Findings

While there is a lot of literature found on parking pricing, travel demand, reducing greenhouse gas emissions (GHG) and improving one's quality of life by not using their car, there was little research found that discusses the direct relationship between reducing (VMT) and parking. There certainly weren't any databases, tools or metrics to be found on the particular two subjects. Urban downtown parking management, which can be directly related to parking pricing is already well- evaluated and developed since the 1970's, however, relating parking prices to reducing VMT has not been directly established. However, most studies included in this report do show a relationship between urban parking pricing/availability with those who opt to take transit instead of driving, thus reducing VMT.

A few mobile cellular phone applications (apps) for parking (Parking Panda, Spot Hero, etc.) were searched on Google, but although they may make it a smarter way to park and offer convenient parking in advance, it doesn't reduce the need for parking. Rather, it is a convenient service offered to those who have already decided to drive and park their car at their destination.

Next Steps

Interview or ask for presentation from Dr. Daniel Chatman, of UC Berkeley, dgc@berkeley.edu, and Dr. Marlon Boarnet, boarnet@price.usc.edu because of their closely related research to the topic at hand, linking land use and transportation policy. Each has agreed to an individual phone conference.

Find other agencies and cities that have implemented parking restrictions, event parking pricing and demand parking management, and interview them, such as the city of Sacramento, CA.

Detailed Findings

Although there were no findings that directly link the relationship of VMT to parking, there were several documents found during this literature review that discuss similar-related issues. The more closely-related reports for the reader to review are highlighted in yellow. The listings are sorted by heading group, with the title of each of the reports or papers shown in **bold**, with the website link listed underneath, and a few paragraphs from the report or article shown below the website link. Main points are italicized in ***bold blue*** for easier, quick reading.

Other States (Google Search)

Transportation Strategies and Parking Technology -Park City Utah
http://www.parkcity.org/departments/parking/parking-management-plan
Free *parking* in *Park* City's most popular yet congested area did not support recommendations and strategies in the General Plan, Traffic and Transportation Master Plan, or the recently adopted Transportation Demand *Management* Plan which estimates that ***parking demand management* can *reduce vehicle miles traveled*.**

Parking Demand Management and Pricing, State of Oregon
http://www.oregon.gov/ODOT/Planning/Documents/Mosaic-Parking-Demand-Management-Pricing.pdf

What is it? Parking demand management strategies include a number of policies and programs designed to reduce parking demand, preserve parking for certain trip types and users, and promote a shift from single occupant vehicle (SOV) trips to transit, pedestrian, and bicycling trips. Parking demand management includes both parking pricing and supply-side strategies. Parking pricing involves charging a fee for parking, whereas parking supply strategies involve restricting the supply of available parking to achieve a desired outcome.

Built Environmental Policies to Reduce Vehicle Travel in Massachusetts July 2016

http://docs.trb.org/prp/17-02040.pdf

Smart growth policies that reduce the distance between origins and destinations and facilitate non-auto modes of transportation present one of the most plausible paths towards a long term reduction in total vehicle-miles traveled (VMT) and associated emissions. While the implementation of any single smart growth policy may make only a small change in travel behavior, the combined effect of multiple changes to the built environment can be substantial. The goals of this study were to determine— using land use, demographic, and ***passenger VMT data for the Commonwealth of Massachusetts***—the importance of built environment variables in influencing household vehicle-miles traveled, and to evaluate the passenger VMT reduction potential of smart growth policy packages in the state.
Among the built environment variables evaluated, land use mix (the average distance between homes and the nearest retail establishment) and household density had the largest impacts on passenger VMT. Other built environment variables found to exert significant influence on passenger VMT include sidewalk coverage, intersection density, managed parking, and the distance from homes to the nearest transit stop. By enacting policies to change these built environment variables, Massachusetts could reduce statewide passenger VMT by 13.6% below the business-as-usual scenario by 2040. If policies to shift projected population gains in the state towards lower-VMT communities are enacted in addition to these built environment changes, VMT could be reduced by more than 15%.

The Climate Change Condition Between Land Use and VMT - City of Gridley, California
http://www.kittelson.com/work/city-of-gridley-climate-action-plangreenhouse-gas-reduction-plan-vehicle-miles-traveled-estimate-tool/

VMT Estimation Tool

Challenge The City of Gridley wanted to produce a Climate Action Plan/Greenhouse Gas Reduction Plan to incentivize sustainable development, infill, and reinvestment that reduce greenhouse gas emissions and to improve the physical and economic conditions of economically disadvantaged neighborhoods.
Solution ***The Kittelson team worked to develop a custom tool that estimates VMT reductions associated with land use mix, density, design, and transit access.*** The tool would assess the control efficiency for reducing on-road vehicle activity of various transportation and land use measures and/or combinations of these measures.
The factors evaluated include:

- Density, community design, and land use mix
- Pedestrian amenities, bicycle amenities, and traffic calming measures
- Parking policies and management
- Car-sharing facilities, bicycle-sharing facilities, and ride-sharing programs
- Transit service frequency and accessibility, inter-modal transit connections, and park-and- ride facilities
- Transportation system management, such as system optimization
- Alternative fueled or hybrid vehicles

The Outcome The Climate Connection Between Land Use and VMT Kittelson created a prioritized list of transportation and land use measures that would result in the highest net benefit with respect to greenhouse gas emissions reduction. Adopted in November 2016, the Climate Action Plan/Greenhouse Gas Reduction Plan outlines actions that are achievable and measurable, and will help the City of Gridley implement emission reductions.

NAIOP Reducing Car Traffic with Transportation Demand Management – S. Black, Development Magazine 2016
https://www.naiop.org/en/Magazine/2016/Summer-2016/Business-Trends/Reducing-Car-Traffic-With-Transportation-Demand-Management.aspx

Parking- Developers can negotiate a reduction in the amount of parking the municipality requires in new construction; in some cases, they can avoid including any parking. (See "Smaller Cities Lighten Up on Minimum Parking Requirements.") In any case, ***avoid building too much parking, which encourages SOV use.*** Design garages to accommodate vans and provide "preferred" spaces for carpooling and vanpooling vehicles. Unbundle parking from residential and office space sales or leases; charge market prices for parking space. In short, use the market and allow for choice.
Install electronic signs directing drivers to the nearest lots, garages or levels with available spaces. Finally, design and build parking garages so they can be retrofitted as commercial or residential space, if and when residents, employees and customers start driving less. Stanford University operates a free public shuttle system that transports staff and students the "last mile" between the campus and local transit, parking, shopping and dining destinations.

Environmental Protection Agency (EPA)

EPA Science Inventory National Service Center for Environmental Protection (NSCEP) of Similar Topics Listing for Parking
https://nepis.epa.gov

Parking Management Strategies for Reducing Automobile Emissions -EPA Science Inventory National Service Center for Environmental Protection (NSCEP) May 1976

There are several reports similar to this one in the 1970's in the EPA NSCEP National Service Center for Environmental Publications.

This report defines the concept of parking management and explores how parking management can be used to improve air quality, support mass transit, reduce energy consumption and improve the amenities of life in urban areas. Specific aspects of this analysis were developments of a prototype parking management plan for the Washington, D.C. metropolitan area illustrating types of measures which can be used for parking management; evaluation of the socioeconomic impacts of parking measures in the plan and their effectiveness in reducing vehicle miles traveled (VMT) and improving air quality; development of a parking management planning process which integrates local and region wide planning through the use of regional guidelines. Four target areas in the D.C. region were studied in detail: the D.C. Core, Rosslyn, Va., Silver Spring, Md., and Centreville, Va. A regional plan was then developed from information gathered in the target area studies, including an analysis of region wide parking related goals and problems.

Parking Cash Out- Implementing Commuter Benefits Under the Commuter Choice Leadership Initiative – 2001
Under a parking cash out program, an employer gives the employee a choice to keep a parking space at work, or to accept a cash payment to give up the parking space.

Parking Spaces Community Places Finding the Balance Through Smart Growth Solutions – U.S. EPA Guidebook of the Development, Community and Environmental Division Jan 2006

See Appendix for Report

This guidebook was compiled by the US EPA's Development, Community, and Environmental Division (DCED) and contractors using existing and new case studies, current bibliographical research and interviews with experts. ***It adds to this collection of resources, pointing communities and developers to proven techniques for balancing parking and other goals to enhance the success of new compact walkable places. Parking indirectly affects the environment (air pollution) primarily because parking influences travel. In convenient, low density single use development, people chose to drive everywhere, resulting in more vehicles miles travelled.*** The report begins with a discussion of the demand for parking and a review of the costs of parking. The following sections detail innovative techniques and case studies explain how they have been used to solve parking problems in specific places. ***It discussed innovative parking alternatives such as reducing over supply, managing demand and pricing strategies. Several case studies include: Portland, OR, Arlington County, VA., Santa Clara, CA. Wilton Manors, FL., Redmond VA., and Long Beach, CA.***

Metrans University Transportation Center (Metrans UTC)

In partnership with the University of Southern California and California State University, Long Beach
https://www.metrans.org/metrans-utc

Urban Spatial Structure and Potential for VMT Reduction - M. Boarnet 2014
https://www.metrans.org/research/urban-spatial-structure-and-potential-vmt-reduction

The evidence on land use and travel shows that employment access has a larger association with travel than population density. In a policy world that is focused on links between residential density and travel, the more important path is possibly (likely) from employment density to travel. SB 375 is at heart an attempt to change urban form in ways that will meet specified GHG reduction targets. This requires clear evidence ***that links from urban spatial structure to travel behavior.***

To date (September, 2015), we have obtained access to the 2012 California Household Travel Survey through the NREL geoportal which allows secure access to household location data. We have used the travel survey data to obtain information on daily vehicle miles traveled (VMT) for each household, and have analyzed the household VMT data descriptively. We have identified employment sub-centers in the Los Angeles region using data from the National Employment Time Series (NETS). ***We have completed preliminary regression analysis of household VMT as a function of spatial access to employment centers.***

National Center for Sustainable Transportation (NCST)

https://www.metrans.org/uc-davis-national-center-sustainable-transportation
https://ncst.ucdavis.edu/research/

When Do Local Governments Regulate Land Use to Serve Regional Goals? Results of a Survey Tracking Land Use Changes that Support Sustainable Mobility GC Sciara Aug 2017
https://ncst.ucdavis.edu/project/tracking-land-use-changes-that-support-sustainable-mobility/

Smart Growth: This paper explores the responses of California cities and counties to this experiment as a way of contributing new insights about what makes local governments more or less likely to collaborate with regionally oriented policies. It reports the results of a survey-based study of California local governments administered in early 2017. The survey study undertaken attempted to quantify whether and to what extent local governments are supporting SB 375 implementation with their land use and development decisions. Overall, ***we found that cities do not uniformly include in their zoning codes land use strategies to promote smart growth.*** On average cities use about five of eight of the strategies, and policies to increase mixed use, infill development, and building density appear most common.

ABSTRACT: An unprecedented effort to improve regional coordination and land use governance has been underway in California since 2008, when the state passed the Sustainable Communities and Climate Protection Act (Senate Bill 375). The law complements earlier state policy (Assembly Bill 32) to reduce statewide greenhouse gas emissions across an array of sectors. SB 375 specifically encourages regional land use planning that, when coupled with supportive transportation investments, would help to reduce automobile dependent patterns of land use and sprawl. Implementation of these new regional land use visions and the GHG reductions they promise depend largely on local government land use and development actions.

California Air Resources Board (CARB)

https://ww2.arb.ca.gov/

Policy Brief on the Impacts of Parking Pricing and Parking Management on Passenger Use and Greenhouse Gas Emissions - S. Spears, UCI, M. Boarnet, USC, S. Handy, UCD September 2014
https://www.arb.ca.gov/cc/sb375/policies/pricing/parking_pricing_brief.pdf

Increasing existing parking prices, or charging for parking that is currently offered for free, has the potential to reduce vehicle travel (as measured by vehicle miles traveled (VMT)) and encourage mode switching by increasing the cost of private vehicle trips. As a result, it may also have the potential to reduce greenhouse gas emissions. Several parking pricing strategies exist, including:

- ***Long/Short Term Fee Differentials***
- ***On Street Fees and Resident Parking Permits***
- ***Workplace Parking Pricing***
- ***Reduced Reliance on Minimum Parking Standards***
- ***Adaptive Parking Pricing***

Long/Short-Term Fee Differentials: Charging different fees for short versus long-term parking can change turnover rate and user mix. For instance, implementing higher fees for long-term parking can help to discourage commuter parking and make more spaces available for shoppers and other short-term users. Such a policy has the potential to encourage carpooling and mode switching without hindering commercial activity.
On-street Fees and Resident Parking Permits: These tools can be used to manage parking congestion and increase turnover to favor short-term parking. Resident parking permits can help

to control spillover of commuter parking into residential areas, and can play an important parking demand management role in conjunction with workplace or commercial parking policies.

Workplace Parking Pricing: Studies have found that approximately 95 percent of employees park at their workplace for free. Because free workplace parking is primarily the result of employer subsidies, programs have targeted these subsidies in an attempt to manage private vehicle travel demand. Other examples of workplace parking pricing include charges for single occupant vehicles and cash-out programs that offer employees cash in lieu of subsidized parking.

Reduced Reliance on Minimum Parking Standards: Minimum parking requirements, usually based on the type and square footage of a parcel's land use, have long been common in U.S. cities (Weinberger, et al., 2010). These requirements often result in an over-supply of parking. Willson (1995), in a study of ten developments in southern California, found that seven of the ten built exactly the minimum parking required and that peak-period parking utilization rates were 56 percent in five "typical" sites and 72 percent in five "special" sites, suggesting that the minimum standard led to excess supply of on-site parking. A few cities, such as Boston, Portland, and New York City, eliminated minimum parking requirements for development projects in the 1970s, and San Francisco instituted a maximum rather than a minimum parking requirement (Weinberger, et al.2010).

Adaptive Parking Pricing: Adaptive pricing adjusts parking prices to obtain a target on-street occupancy rate. It does this by varying the prices by location and time of day to balance parking supply with demand on a block-by-block basis. This is the most sophisticated use of pricing to manage parking demand. San Francisco pioneered the use of adaptive parking pricing with SFpark, which was implemented in seven pilot zones in 2011.

Impacts of Parking Pricing Based on a Review of Empirical Literature- Technical Background Document S. Spears, M. Boarnet, S. Handy Dec 2013
https://www.arb.ca.gov/cc/sb375/policies/pricing/parking_pricing_bkgd120313.pdf

There are relatively few academic studies that examine the impacts on vehicle miles traveled (VMT) of parking pricing. However, much of what has been done is directly applicable to the conditions that exist in the major urbanized regions of California. Examples include Deakin et al. (1996) and Shoup (1994, 1997, 2005). These studies differ in both methodology and scope. Deakin et al. used outputs of the Short-range Transportation Evaluation Program (STEP) travel demand model to examine regional VMT impacts of parking pricing. Shoup (1997) used case studies of individual workplaces to examine the impacts of site -specific parking policies on employee VMT. Including both approaches gives the reader a better picture of the potential VMT impacts from policies of varying scope.

In addition to these studies, ***our review included documents that examined multiple parking pricing studies.*** Among these were Chapter 13 of the Transit Cooperative Research Program (TCRP) Report 95: Parking Pricing and Fees (2005) and Rodier's (2008) review of parking pricing models. These two documents include the California studies mentioned above, as well as other U.S. and international examples. From the studies cited in these documents, the most relevant were examined individually. Those that were both relevant and methodologically sound were included in the review. These included Dueker et al. (1998), which also used outputs of the STEP model to evaluate regional parking pricing impacts in California and Seattle. The European PROPOLIS modeling study, cited by Rodier, was included as well, because it is one of a very small number that ***examine the regional VMT impacts of parking pricing***. PROPOLIS also used a comprehensive travel demand and land use model to examine policy impacts over various time periods.

The final set of studies that were included in this review were those that were concerned with elasticities of demand for parking spaces. Shoup's (1994) study of U.S. and Canadian cities was useful because it examined parking behavior in Los Angeles. Historical background on parking demand elasticities was taken from studies reviewed in TCRP 95, including Kulash's 1974 study of San Francisco and Gillen (1977). Kelly and Clinch (2009) was included because it is one of the few recent studies of parking demand elasticity that examines actual (revealed) behavior in a commercial shopping district. They used revealed preference data obtained from parking records to calculate elasticity of demand for parking space in Dublin and controlled for income changes during the study period. Henscher and King (2001), which used stated preference methods and a nested logit model, was also included because it illustrates the potential impact on commercial district parking demand. Kulash (1974) estimated elasticities for parking space demand using historical data, controlling for income and parking growth trends.

A Plan to Efficiently and Conveniently Unbundle Car Parking Costs - M. Bullock & J. Stewart, 2010
https://www.arb.ca.gov/lists/senbill375/1-manuscript18b.pdf

The introduction shows documented driving reductions due to the pricing of parking, such as the car-parking cash-out program that pays employees extra money each time they get to work without driving. It notes that although the benefits of priced and shared parking are known, such parking has not been widely implemented, due to various concerns. It states that a solution, called “Intelligent Parking,” will overcome some of these concerns, because it is easy to use and naturally transparent. Eight background information items are provided, including how priced parking would help California achieve greenhouse gas reduction targets.

A Review of the International Modeling Literature: Transit, Land Use, and Auto Pricing Strategies to Reduce Vehicles Miles Travelled and Greenhouse Gas Emissions- C. Rodier, Transportation Sustainability Research Center Innovative Mobility Research, UC Berkeley Aug 2008
https://www.arb.ca.gov/planning/tsaq/docs/rodier_8-1-08_trb_paper.pdf

As the media document very real evidence of global climate change and the debate over humans’ role precipitating this change has ended, California led the nation by passing the first global warming legislation in the U.S. California is tasked with reducing greenhouse gas (GHG) emissions to 1990 levels by 2020 and 80% below 1990 levels by 2050. The California Air Resources Board estimates that significant GHG reductions from passenger vehicles can be achieved through improvements in vehicle technology and the low carbon fuel standard; however, these reductions will not be enough to achieve 1990 levels if current trends in vehicle kilometers traveled (VKT) continue. Currently, most operational regional models in California have limited ability to represent the effects of transit, land use, and auto pricing strategies; efforts are now underway to develop more advanced modeling tools, including activity-based travel and land use models. In the interim, ***this paper reviews the international modeling literature on land use, transit, and auto pricing policies to suggest a range of VKT and GHG reduction*** that regions might achieve if such policies were implemented. The synthesis of the literature categorizes studies, by geographic area, policy strength, and model type, to provide insight into order of magnitude estimates for 10-, 20-,
30-, and 40-year time horizons. The analysis also highlights the effects of modeling tools of differing quality, policy implementation timeframes, and variations in urban form on the relative

effectiveness of policy scenarios. Transit, Land Use and Congestion Pricing are listed in figures showing VKT reductions in 10 to 20 year horizons. This was presented at the TRB meeting in 2009 and was funded by Caltrans and CARB.

Public Policy Institute of California (PPIC)

http://www.ppic.org/

Driving Change: Reducing Vehicle Miles Travelled in California - PPIC Presented Feb 2011
http://www.ppic.org/event/driving-change-reducing-vehicle-miles-traveled-in-california/
Full Report http://www.ppic.org/content/pubs/report/R_211LBR.pdf

Can Californians cut down on their driving? Encouraging job growth near transit stations will help. So will pursuing policies that raise the cost of driving. This report examines California's progress in these and other areas, finding both opportunities and challenges ahead. The PPIC report assesses how well California's local and regional governments are positioned to meet the targets set under Senate Bill 375. Having jobs near transit is more important in boosting ridership than having housing near transit. The PPIC report notes one more important warning sign: resistance to the use of pricing tools, like higher fuel taxes and road use charges, to discourage solo driving. Local and regional officials are wary of public opposition. But these tools have the highest potential to reduce driving, and they can generate revenue to fill the growing gap in transportation budgets. And spurring transit use is a major challenge, 75% still drive to work alone, and there's no boost in job growth near transit.
What should California do? Encourage job growth near transit, and increase the cost of driving and parking.

Views from the Street: Linking Transportation and Land Use – PPIC Feb 2011
http://www.ppic.org/publication/views-from-the-street-linking-transportation-and-land-use/
Power Point: http://www.ppic.org/content/av/EventBriefing_DrivingChange_02_11.pdf

California is one of the first states in the nation (CA SB 375) to set a goal for reducing residents' driving. This study assesses the response of cities and counties, finding signs for optimism that the state can achieve its goals—as well as obstacles to overcome. Approaches for reduced driving is discussed including: Local programs and perceptions, CA experience with transit orientated development and policy recommendations. Three Primary Approaches for Reducing Driving: 1. Encourage denser development, closer to transit (1/4 mile from station) 2. Invest in transit and other alternatives (walking, biking) 3. Use pricing incentives to raise the cost of driving (e.g. fuel tax, toll lanes, carpool lanes, parking fees/integrate strategies) and Reduced Parking Requirements.

National Center for Sustainable Transportation (NCST)

Institute of Transportation Studies, UC Davis, CA (ITS), with the National Center for Sustainable Transportation (NCST)
https://its.ucdavis.edu/
https://ncst.ucdavis.edu/

A Framework for Projecting the Potential Statewide Vehicle Miles Travelled (VMT) Reduction from State Level Strategies in California NCST UC Davis Metrans White Paper Marlon Boarnet, USC and Susan Handy of UC Davis March 2017
https://ncst.ucdavis.edu/white-paper/framework-for-projecting-the-potential-statewide-vmt-reduction-from-state-level-strategies-in-california/

See Appendix for Report

The California Global Warming Solutions Act of 2006 (Assembly Bill 32) created a comprehensive, multi-year program to reduce greenhouse gas (GHG) emissions in the state. With the recent passage of Senate Bill 32, California has adopted an additional target of reducing greenhouse gas emissions. The California Air Resources Board (ARB) is considering a wide range of strategies for the 2016 Scoping Plan Update that focuses on reducing demand for driving. ***These strategies fall into four general categories: Pricing, Infill Development, Transportation Investments, and Travel Demand Management Programs****.* This white paper examines the evidence available and assumptions needed for projecting statewide Vehicle Miles Traveled (VMT) reductions for each category of strategies. The goal is to provide a framework for projecting the magnitude of reductions that the state might expect for the different strategies. This framework helps to illuminate the sequence of events that would produce VMT reductions and highlights important gaps in knowledge that increases the uncertainty of the projections. Despite uncertainties, the evidence justifies state action on these strategies: **the available evidence shows that the strategies considered in this paper are likely to reduce VMT if promoted by state policy.**

Transportation Research Board (TRB)

www.TRB.org

NCHRP Synthesis 20-05 Topic 48-06- Integrated Transportation and Land Use Models- In Progress
http://apps.trb.org/cmsfeed/TRBNetProjectDisplay.asp?ProjectID=4168

The objective of this project is to develop a synthesis of integrated transportation and land-use models for use by planning agencies with varying resource levels (DOTs, MPOs, etc.). The project will result in a document that allows planning agencies to identify the type of integrated model that fits their needs.
The professor Rolf Moeckel and Jencks Crawford of TRB said in an email on 2-22-18: "*Lee, Crawford is right, parking management was not dealt with in this NCHRP report. This report covered land use models and their integration with transport models. I agree that parking management has a significant impact on both transport and land use, but due to data limitations, our models commonly ignore parking issues. That is a big task we should better capture in models. Best, Rolf."*

NCHRP 25-21 (Final Report 535) Predicting Short-Term and Long-Term Air Quality Effects of Traffic-Flow Improvement Projects
http://www.trb.org/Main/Public/Blurbs/155398.aspx

The total air quality effects of transportation projects, especially those designed to improve

traffic flow, are not fully understood. Projects may result in beneficial or detrimental impacts over the short or long term. For example, traffic-flow improvement projects may have a short-term air quality benefit by reducing congestion and increasing speed yet have a negative effect by facilitating additional travel. Also, transportation actions such as high-occupancy vehicle (HOV) projects, tolling strategies, and ***reduction in parking availability may have long-term air quality benefits by reducing trips and vehicle miles of travel (VMT)***, yet might make air quality worse in the short term by increasing congestion and queuing.
The objective of this research was to develop and demonstrate, in case study applications, a methodology to predict the short-term and long-term effects of corridor-level, traffic-flow improvement projects on carbon monoxide (CO), volatile organic compounds (VOCs), oxides of nitrogen (NOx), and particulate emissions (PM). The methodology should evaluate the magnitude, scale (such as region-wide, corridor, or local), and duration of the effects for a variety of representative urbanized areas. The final report was published as NCHRP Report 535.

Equity in Congestion-Priced Parking, A Study of SF Park, 2011- 2013, D. Chatman and M. Manville
Journal of Transport Economics and Policy, Vol. 52, July 2018

See Appendix for Report

Cities could reduce or eliminate cruising for parking by correctly setting parking meter rates, but would doing so harm lower-income drivers? Does market priced parking disproportionally burden lower-income households? We examined the question using data on more than 17,000 parked vehicles and their drivers from SFpark, a federally funded market-priced parking experiment in San Francisco. ***We found that lower-income parkers are more likely to use street parking.*** We find little evidence that higher-priced parking displaces lower income drivers, either by reducing their parking durations or leading them to park less overall. Meter rates had small effects on usage. Raising prices did not increase sorting across blocks by income. Controlled analysis yielded mixed and weak evidence that lower-income parkers may be more sensitive to price increases. We discuss policy implications.

National Academies Press (NAP)

https://www.nap.edu/

Transit Supportive Parking Policies and Programs - TCRP Synthesis 122 - 2016
TRB's Transit Cooperative Research Program (TCRP) Synthesis 122: Transit Supportive Parking Policies and Programs documents transit agency parking policies and parking management at transit stations using three primary resources: a scan of current research on transit supportive parking policies, an original survey distributed to a sample of transit agencies, and several brief agency profiles based on interviews and existing available data. Participating transit agencies represent a broad spectrum of service type, jurisdiction, ridership, mode, types of parking, and parking policy.

Traveler Response to Transportation System Changes Handbook 3rd Edition – Chapter 18 Parking Management and Supply TCRP Report 95 – TRB 2003

This "Parking Management and Supply" chapter presents information on how travelers respond to differences in the supply and availability of vehicle parking, including changes that might occur as a result of shifting land use patterns, alterations of regulatory policy, or attempts to "manage" the supply of parking. Information on "normal" baseline parking characteristics is also provided. ***The types of parking supply management strategies listed include: Min/Max Parking requirements, Employer, On-Street parking, peripheral parking and park and ride …Parking availability is of significant importance to travelers making travel decisions…The relationship between parking supply and demand is captive to the dominate role of parking pricing…. The governing factor in parking supply is most commonly the building or zoning code requirements of local governments…The primary purposes for parking downtown in larger cities are – in order of importance- work, personal business and shopping… parking is a major urban land use….*** The effects of parking pricing are, however, covered in Chapter 13, "Parking Pricing and Fees." Parking in support of transit service and carpooling is the subject of Chapter 3, "Park-and-Ride/Pool." **Click**

Economics, Demand Management and Parking Policy - Volume 2187, 2010
http://trrjournalonline.trb.org/toc/trr/2187/

Volume 2187 Subtopic: Influence of Parking Policy on Built Environment and Travel Behavior in Two New England Cities, 1960 to 2007 C.McCahill and N.Garrick
http://trrjournalonline.trb.org/doi/pdf/10.3141/2187-16

Over the past 40 to 50 years, most American cities have experienced significant increases in automobile use. Now, to offset increasing energy use and greenhouse gas emissions, many are contemplating measures to reduce automobile use. This study examined Hartford, Connecticut, and Cambridge, Massachusetts, which exhibited an increase and a decrease in automobile use, respectively, between 1960 and 2007. It is hoped that these cities provide lessons in how to successfully reduce automobile travel. The study focused on the ***cumulative effects of historical policy decisions over decades on parking provisions and changes in travel behavior.*** The results of this analysis suggest that parking policy affects incremental changes in parking provision that may greatly influence gradual changes in automobile use over time. Cambridge now has the most diverse transportation system of any American city of its size and over the past decade had become increasingly less automobile oriented.
Trends in Hartford indicate that ***incremental increases in parking provide incentives to drive*** and disincentives to walk or bike that may greatly influence gradual changes in travel behavior. In Cambridge decreasing automobile use may be associated with deliberate disincentives to drive (such as limited parking) and careful preservation of the built urban environment. These findings are promising, but a larger study with additional cities will help isolate the effects of different factors and strengthen the link between policy, the built environment and travel behavior over time. The authors believe that his line of inquiry could lead to a better understanding of policies for bringing about robust reductions in automobile dependency in American cities.

California Department of Transportation (Caltrans)

http://www.dot.ca.gov/

Public Transportation and Industrial Location Patterns in California – D. Chatman UC Berkeley 2016
http://www.dot.ca.gov/research/researchreports/reports/2016/CA16-2869_FinalReport.pdf

Existing land use patterns and policies may play a greater role in the varying magnitude of rail influence on employment density and land value than the availability of rail access itself, and that downtown Los Angeles (LA) and San Francisco Bay Area (SF) benefit more from rail than the outlying parts of the metropolitan areas. This project investigated how changes in rail transit service in California metropolitan areas of LA and SF are associated with the concentration of firms and commercial property values. ***The role of parking is significant in the Santa Monica area of LA in relationship to real estate development.*** (There is a section in the role of parking in this document). While interviewees hope that people will utilize rail, they admit that any property would be struggling to lease if there is inadequate parking provisions. Regulations that dictates high levels of parking construction is a limiting factor in parts of LA, and maximizing parking flexibility rather than requiring minimum parking will incentivize developments. In SF, tenants are willing to pay the high cost of parking and developers are able to over - sell parking by 15 - 25% to satisfy tenants' demands. SF also has high-tech companies with higher end employees only wanting to walk less than 15-20 minutes from BART to a building. They want to be located near public transportation and a nice location with amenities or will probably not want to work there. Parking demand do not seem to be relaxing thus far in LA. In fact, one interviewee believes that the move towards rail will only create more demand for parking structures near rail stations. This interviewee is focused on acquiring properties for dedicated parking structures near rail stations. In SF, there is a steady decrease in driving in the city and young tech workers want to be in urban environments close to amenities and transit.

Impact of Active Transportation on Reducing or Avoiding Vehicle Miles Traveled and Greenhouse Gas Emissions – Preliminary Investigation Jan 2016
http://www.dot.ca.gov/research/researchreports/preliminary_investigations/docs/active_transportation_preliminary_investigation_1-21-16.pdf

CTC & Associates examined published and in-process research and other relevant publications related to active transportation in the following topic areas:
• Tools, models and other practices that quantify the impact of active transportation on GHG and VMT avoidance or reduction in both rural and urban active transportation projects.
• Metrics that allow a transportation agency to associate a specific active transportation project with an expected impact on GHG and VMT.
• Policies, strategies and characteristics of the built environment that encourage the use of active transportation.
To supplement the results of this literature review, we contacted representatives from selected transportation agencies expected to have experience with quantifying the impact of active transportation projects on VMT and GHG.
The literature search uncovered limited general guidance associated with models or tools to estimate the impacts of active transportation on VMT and GHG emissions. Some of that guidance indicates that the models and tools are evolving and require further development. For example, a 2014 NCHRP guidebook includes profiles of models used to address bicycle and pedestrian travel behavior and demand. Of those models that permit analysis at the project/site level, ***none include a metric for VMT.*** A Safe Routes to School National Partnership publication also examines the pros and cons of modeling strategies.
The model developed for the Nonmotorized Transportation Pilot Program, which supplied funding to four pilot communities to construct nonmotorized facilities, provided "an innovative approach to estimating averted VMT and changes in walking and bicycling mode share" using location counts and data from the National Household Travel Survey. While focused on estimating the public health benefits of active transportation at a regional level, the Integrated

Transport and Health Impacts Model (I-THIM) also estimates reductions in GHG emissions associated with higher levels of active transportation.

Methodologies to Convert Other Modes of Travel to Vehicle Miles Traveled (VMT) - Preliminary Investigation 2015
http://www.dot.ca.gov/research/researchreports/preliminary_investigations/docs/modes_to_miles_preliminary_investigation_7-6-15_final.pdf

To assist Caltrans in identifying methods to quantify mode shift from vehicles to local buses, CTC & Associates reviewed research and guidance related to transit-oriented development (TOD) and smart mobility place types such as urban centers, compact communities and rural lands. To supplement this research, CTC contacted experts in the field for help in identifying measurement efforts underway nationally that were not readily available in the published literature.

Development and Application of an Integrated Health Impacts Assessment Tool for Assessing the Health Impacts of Transportation Plans in Sacramento – NCST - London, Karner, Rowangould, Wu, Igbinedion, February 2018
https://regionalchange.ucdavis.edu/publication/development-and-application-integrated-health-impacts-assessment-tool-sacramento-region
Our results demonstrate the utility of analyzing and representing the public health impacts of transportation plans in a user-friendly way for planners, policy makers, and advocates. The methodology used in this project can serve as a model for those working on active transportation, public health, and regional equity in other locations across the US. The aim of the project is to investigate the distribution of public health impacts resulting from a regional transportation plan in the six-county region of Sacramento Area Council of Government's (SACOG) region. The report summarizes three goals:

1. Comparison of different approaches to assessing the public health impacts of transportation plans.
2. Employ a refined version of the Integrated Transportation Health Impacts Model (ITHIM) to quantify health impacts resulting from the 2016 SACOG Metropolitan Transportation Plan/Sustainable Communities Strategy
3. Report on the development of a user-friendly web interface for summarizing ITHIM results

The interactive web ITHIM-Sacramento Equity Analysis Tool can be viewed at https://aakarner.shinyapps.io/06_equity_analysis

All source code and model documentation are available at https://github.com/aakarner/ITHIM-Sacramento
Caltrans 2010-2013 California Household Travel Survey - June 2013
http://www.dot.ca.gov/hq/tpp/offices/omsp/statewide_travel_analysis/Files/CHTS_Final_Report_June_2013.pdf

Mode Choice 8.3.1: As indicated, auto was the dominant mode throughout the region, accounting for about 76% of all trips (49.6% as drivers and 26.4% as passengers).

Alyssa Begley, Caltrans – Other Resource Links

SB 743 Program Implementation Manager/Sustainability Program
The following research papers are used by the Big Cities and should be considered within the preliminary investigation for the Parking Utilization and Site Level Vehicle Miles Traveled (VMT) Database.

Does TOD Need the T? – The Importance of Factors Other Than Rail Access
Journal of the American Planning Association (JAPA) Vol 79 2013 Issue 1 D. Chatman
https://www.planning.org/
https://www.tandfonline.com/doi/abs/10.1080/01944363.2013.791008

See Appendix for Report

Contrary to popular belief, the sacred "T" in TOD may not be necessary for reduced car dependence- -A Wachs - Dec 2015 The Architects Newspaper Dec 2015 -
https://archpaper.com/2015/12/contrary-popular-belief-sacred-t-tod-may-not-necessary-reduced-car-dependence/

Urban planning credo states that, through design and policy interventions that improve access to public transportation, Transit-Oriented Development (TOD) reduces car dependency and encourages individuals to walk, bike, bus, or take the train to their destination. Well, maybe. A University of California, Berkley study suggest that, for rail, the T in TOD may not be necessary to reduce car travel in neighborhoods that are dense and walkable, with scarce parking.

In a study of rail transit's impact on travel patterns, Daniel Chatman, associate professor in the Department of City & Regional Planning at UC Berkeley, challenged the assumption that easy access to rail leads to less reliance on cars (and subsequently lower rates of car ownership). Were there other factors at play, like narrower streets, good parking, wider sidewalks, and nearby destinations?

Chatman received over 1,100 responses to a survey he sent to households living within a two-mile radius of ten New Jersey train stations, within commuting distance to Manhattan. Chatman asked residents about what type of house they lived in, on- and off-street parking availability, travel for work and leisure, residential location preferences, and household demographics. 30 percent of respondents lived in housing that was less than seven years old. Half lived within walking distance (0.4 miles) to rail, in TOD-designated and non-designated developments. ***Controlling for housing type, bus access, amount of parking, and population density, among other markers, the availability of on- and off-street parking, not rail access, was the key determinate in auto ownership and car dependence.*** The study asserts that "households with fewer than one off-street parking space per adult had 0.16 fewer vehicles per adult. Households with *both* low on- and off-street parking availability had 0.29 fewer vehicles per adult." Living in a new house near a train station, moreover, was correlated with a 27 percent lower rate of car ownership compared to residents further afield.

Bus access was also key in determining car use. The number of bus stops within one mile of a residence is a good indicator of public transit accessibility, and there are usually more bus stops in denser areas. The study found that "doubling the number of bus stops within a mile radius around the average home was associated with 0.08 fewer vehicles per adult." Compared to areas with poor bus access and plentiful parking, car ownership was reduced by 44 percent when strong bus access converged with poor parking availability.

To reduce car ownership and use, municipalities don't necessarily have to invest in rail. ***Reducing the availability of parking, providing better bus service, developing smaller***

houses (and more rentals), and creating employment centers in walkable, densely populated downtowns may accomplish the same objective, at considerably less expense.

Robert (2010) Travel and the Built Environment, Journal of the American Planning Association, Vol 27, Feb 2009 2010 Issue 3 Ewing, Reid and Cervero
http://www.tandfonline.com/doi/abs/10.1080/01944361003766766
Unable to download the entire article, need subscription

Problem: Localities and states are turning to land planning and urban design for help in reducing automobile use and related social and environmental costs. The effects of such strategies on travel demand have not been generalized in recent years from the multitude of available studies.
Purpose: We conducted a meta-analysis of the built environment-travel literature existing at the end of 2009 in order to draw generalizable conclusions for practice. We aimed to quantify effect sizes, update earlier work, include additional outcome measures, and address the methodological issue of self-selection.
Methods: We computed elasticities for individual studies and pooled them to produce weighted averages.
Results and conclusions: Travel variables are generally inelastic with respect to change in measures of the built environment. Of the environmental variables considered here, none has a weighted average travel elasticity of absolute magnitude greater than 0.39, and most are much less. Still, the combined effect of several such variables on travel could be quite large. Consistent with prior work, ***we find that vehicle miles traveled (VMT) is most strongly related to measures of accessibility to destinations and secondarily to street network design variables.*** Walking is most strongly related to measures of land use diversity, intersection density, and the number of destinations within walking distance. Bus and train use are equally related to proximity to transit and street network design variables, with land use diversity a secondary factor. Surprisingly, we find population and job densities to be only weakly associated with travel behavior once these other variables are controlled.
Takeaway for practice: The elasticities we derived in this meta-analysis may be used to adjust outputs of travel or activity models that are otherwise insensitive to variation in the built environment, or be used in sketch planning applications ranging from climate action plans to health impact assessments. However, because sample sizes are small, and very few studies control for residential preferences and attitudes, we cannot say that planners should generalize broadly from our results. While these elasticities are as accurate as currently possible, they should be understood to contain unknown error and have unknown confidence intervals. They provide a base, and as more built-environment/travel studies appear in the planning literature, these elasticities should be updated and refined.

Effects of Parking Provision on Automobile Use in Cities: Inferring Causality – C McCahill, N Garrick, C Palombo and A Polinski
http://trrjournalonline.trb.org/doi/10.3141/2543-19

Many cities include minimum parking requirements in their zoning codes and provide ample parking for public use. However, parking is costly to provide and encourages automobile use, according to many site-specific studies. At the city scale, higher automobile use is linked to traffic congestion, environmental degradation, and negative health and safety impacts, ***but there is a lack of compelling, consolidated evidence that large-scale parking increases cause automobile use to rise***. In this study, the Bradford Hill criteria, adopted from the field of epidemiology, were applied to determine whether increases in parking should be considered a likely cause of citywide increases in automobile use. Prior research and original data from nine U.S. cities dating to 1960 were relied on. It was found that an increase in parking provision from 0.1 to 0.5 parking space per person was associated with an increase in automobile mode share of roughly 30 percentage points. It was also demonstrated that a majority of the Bradford Hill criteria could be satisfied by using the available data; ***this finding offers compelling evidence that parking provision is a cause of citywide automobile use. Given the costs associated with parking and its apparent effects on automobile use, these findings warrant policies to restrict and reduce parking capacity in cities.***

Spears, Boarnet, Handy. 'Policy Brief on the Impacts of Voluntary Travel Behavior Change Programs Based on a Review of the Empirical Literature' 12/3/2013
See TRB Section of this Literature Search

Weinberger, R., Death by a thousand curb-cuts: Evidence on the effect of minimum parking requirements on the choice to drive.   Transport Policy Mar 2012 R. Weinberger
https://www.researchgate.net/publication/238503397_Death_by_a_thousand_curb-cuts_Evidence_on_the_effect_of_minimum_parking_requirements_on_the_choice_to_drive
[accessed *Research Gate: Cannot download*

Little research has been done to understand the effect of guaranteed parking at home—in a driveway or garage—on mode choice. The research presented here systematically examines neighborhoods in the three New York City boroughs for which residential, off-street parking is possible but potentially scarce. The research is conducted in two stages. Stage one is based on a Google Earth© survey of over 2000 properties paired with the City's tax lot database. The survey and tax lot information serve as the basis to estimate on-site parking for New York City neighborhoods. With parking availability estimated, a generalized linear model, using census tracts as the unit of analysis, is used to estimate the maximum likelihood parameters that predict the proportion of residents who drive to work in the Manhattan Core. ***The research shows a clear relationship between guaranteed parking at home and a greater propensity to use the automobile for journey to work trips*** even between origin and destinations pairs that are reasonably well and very well served by transit. ***Because journey to work trips downtown for most cities, and New York City is no exception, is most easily served by transit, we infer from this finding that non-journey to work trips is also made disproportionately by car from these areas of high on-site parking.***

Parking Demand Technology

Parking Panda- On Demand Parking Deals
https://www.parkingpanda.com/
https://itunes.apple.com/us/app/parking-panda/id550285323?mt=8

On your cellphone, search and compare all available parking options and prices in 40+ cities, book and pay for a guaranteed spot. Stop wasting time circling the block looking for the perfect parking spot! The ***Parking Panda iPhone app allows you to easily and quickly search for, reserve, and redeem parking in major cities nationwide.*** Best of all, find and book rates that are guaranteed to be cheaper than drive-up at select locations! Download the parking app for free!
Whether you're looking for parking near the office, the airport, the stadium, the museum, or

wherever else your travels take you, Parking Panda enables you to book guaranteed parking at over 2,500 lots, garages, airports and valets… We update our app regularly to bring you new features and bug fixes.

Hero Tech- Spot Hero
https://spothero.com/herotech/

HeroTech is a suite of digital parking tools built to accelerate revenue for venues, lots and garages. It's everything you need to process speedy payments, create operational efficiency and provide a frictionless parking experience – all in one multi-talented platform.
Event Hero- Speed up and streamline end-to-end event parking operations, Valet Hero- Nix the tickets and provide a fully digital valet experience, VIPHERO- Tool for Valet Attendants to quickly create and send comped or validated parking passes. Over the past two years, Tampa Bay Rays have parked 286,162 cars at an average of just 3 seconds each. The company offers ways to book parking, sell parking for property owners and offer parking solutions for venues and businesses.

Parkmobile
http://us.parkmobile.com/

Reserve your perfect parking space. Download the app, open an account, then look for a Parkmobile sign or sticker, enter zone number listed on the sign to start the parking session, and that's it! And to make life easier, you can opt-in to receive a notification prior to your parking session expiring.

Appendix

Parking Spaces / Community Places

Finding the Balancethrough Smart Growth Solutions

Parking Spaces / Community Places

Finding the Balance through Smart Growth Solutions

Development, Community, and Environment Division (1807T)
U.S. Environmental Protection Agency
Washington, DC 20460

EPA 231-K-06-001
January 2006

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Introduction

When you shop, you may visit a mall, or go to your town's main street. At the mall, you probably cruise past rows and rows of empty parking, the spaces filled only one day a year. Maybe you head downtown, but can only find vacant storefronts. And where things are bustling, you can't find convenient parking near the stores you want to visit. All three of these scenarios represent a "parking problem" that has a negative impact on other community goals. At the mall, overbuilt parking consumes land and wastes money. Downtown, storefronts may sit empty because new businesses that would like to move in can't meet high parking requirements – and too little parking makes good businesses less viable.

But what does parking have to do with the environment, and the U.S. Environmental Protection Agency (EPA)? Research and reports from EPA and others show that the way we develop our communities has a major impact on the quality of the natural environment. Regions with walkable, mixed-use, compact neighborhoods, towns, and cities, knit together by a robust network of transportation and environmental corridors, protect human health and the natural environment. The research shows that development reflecting smart growth principles can lead to reduced growth in air pollution and less polluted runoff into streams and lakes. It also leads to a reduction in the amount of pristine land consumed by development, which can help preserve habitat for many species. Air pollution is reduced because such compact areas make it easier for some people to choose to walk and bike for some trips, and others will be able to drive shorter distances or take transit. Along with fewer and shorter trips by car comes a reduced need for parking, and that means less land needs to be paved for parking lots or garages. That reduces development costs and leaves more open ground that can filter rainwater, and more open space for birds, animals, and people to enjoy. For a thorough discussion of the connections between development patterns and environmental quality, see *Our Built and Natural Environments: A Technical Review of the Interactions Between Land Use, Transportation, and Environmental Quality* (EPA, 2001a).

Many communities are evaluating parking issues as part of a broader process of reevaluating their overall goals for growth. They want and need new residents and jobs – for vitality, economic growth, and other reasons – but they need to decide how and where to accommodate them. In cities, towns, and countryside, new and newly rediscovered development patterns offer solutions. In many places, walkable town centers that offer stores, workplaces, and housing in close proximity are replacing malls and office parks, offering shops and dining along with places to live and work. New neighborhoods offer different housing types and daily conveniences within a pleasant, safe walking distance. Vacant, underused and contaminated sites can be reclaimed and benefit their communities with new jobs and housing, improved recreational opportunities, and increased fiscal stability. Many communities are working to offer choices to residents, so they can take a train, ride a bike, or walk instead of driving, if that is what is best for them and their families. Whether the resulting development patterns are called smart growth, quality growth, or balanced growth, they work by creating great places.

Communities and developers recognize that compact, mixed-use, walkable places need parking to thrive. Retail activity in particular requires convenient parking spaces that can handle high turnover. Businesses almost always need some parking for their employees, but the amount needed can vary widely. The need for parking may shift throughout the day as people come to shop, employees head to work, and residents go out for the evening. Residents and employees in more compact areas usually own fewer cars and drive less than is typical in conventional developments. Yet typical parking regulations and codes simply require a set amount of parking for a given square footage or number of units, assuming all trips will be by private automobile and ignoring the neighborhood's particular mix of uses, access to transit and walking, and context within the metropolitan region. Such inflexible parking requirements can force businesses to provide unneeded parking that wastes space and money. The space and money devoted to unnecessary parking could be used to accommodate other homes, businesses, shopping, or recreational opportunities in the community. In some cases, rigid parking standards can discourage or even prevent development, because providing it is just too expensive -- and developers are usually offered no alternative.

In cities and counties across the country, inflexible minimum parking requirements are the norm -- but they represent a barrier to better development, including redevelopment of vacant city land and contaminated sites. EPA developed this guide for local government officials, planners, and developers in order to:

- demonstrate the significance of parking decisions in development patterns;
- illustrate the environmental, financial, and social impact of parking policies;
- describe strategies for balancing parking with other community goals; and
- provide case studies of places that are successfully using these strategies.

The policies described in this report can help communities explore new, flexible parking policies that can encourage growth and balance their parking needs with their other goals. The case study in this report of the SAFECO Corporation (see page 50) illustrates the potential to use parking policies to save money, improve the environment, and meet broader community goals. SAFECO has its corporate headquarters in the Seattle region. To accommodate new employees, this insurance company built three new buildings and underground parking garages. In an effort to balance parking needs with their financial, environmental, and design goals, they choose to offer employees transit passes, vanpool and rideshare incentives, or parking. Over 40 percent of SAFECO's employees choose an alternative to driving alone. As a result, each year SAFECO's 1700 employees drive about 1.2 million miles less than average commuters in the Seattle region, saving 28 tons of carbon monoxide, a serious pollutant tracked by the EPA. SAFECO also reduced the amount of ground that needed to be paved by 100,000 square feet, leading to less runoff in this rainy area. The company saves an estimated $230,000 per year, after accounting for the costs of incentives and the savings from reducing the amount of parking built.

Several EPA programs recognize the superior environmental performance of alternatives to driving alone and to conventional low-density, single-use development patterns. For example, EPA and the U.S. Department of Transportation sponsor the successful Best Workplaces for Commuters program (EPA, 2005a), which advocates employer-provided commuter benefits that encourage shifts from long-distance solo driving and parking. On a regional level, EPA offers areas that wish to recognize the emissions benefits of smart growth guidance for "Improving Air Quality Through Land Use Activities" (EPA, 2001b). EPA has also published "Protecting Water Resources with Smart Growth" (EPA, 2004), which includes 75 policies and programs that help meet water quality and other community goals. EPA and its partners in the Smart Growth Network (see box) also offer very successful resources on the policies and actions that create smart growth. "Getting to Smart Growth" (ICMA, 2002) and "Getting to Smart Growth II" (ICMA, 2003), published by the International City/County Management Association and the Smart Growth Network, detail 200 policies that communities have used to create new development to serve the needs of their residents and businesses, local governments, and the environment. For more information on these and other resources, and instructions on how to receive them, visit www.epa.gov/smartgrowth.

This report adds to this collection of resources, pointing communities and developers to proven techniques for balancing parking and other goals to enhance the success of new compact walkable places. The report begins with a discussion of the demand for parking and a review of the costs of parking. The following sections detail innovative techniques and case studies explain how they have been used to solve parking problems in specific places.

Principles of smart growth

Smart growth is development that serves communities, the economy, public health, and the environment. The original Smart Growth Network partners articulated the following principles describing smart growth, based on their experience in communities nationwide. These principles have since been adopted by many organizations and communities to help describe the development patterns they seek to create.

1. Mix land uses.

2. Take advantage of compact building design.

3. Create a range of housing opportunities and choices.

4. Create walkable neighborhoods.

5. Foster distinctive, attractive communities with a strong sense of place.

6. Preserve open space, farmland, natural beauty, and critical environmental areas.

7. Strengthen and direct development toward existing communities.

8. Provide a variety of transportation choices.

9. Make development decisions predictable, fair, and cost-effective.

10. Encourage community and stakeholder collaboration in development decisions.

For more information, visit www.epa.gov/smartgrowth.

About the Smart Growth Network

The Smart Growth Network, formed in 1996, is a loose coalition of organizations and individuals that believe that where and how we grow is important to our communities, health, and environment. The network is led by a partnership of over thirty private sector, public sector, and nongovernmental organizations that work to help create better development patterns in neighborhoods, communities, and regions across the United States. It also includes a membership organization of over 900 individuals, community organizations, and other stakeholder groups. These organizations endorse the principles listed on the previous page.

The Smart Growth Network partners range from planners and architects to developers and financiers and funders, from community advocates to traditional environmentalists, from real estate agents to transportation engineers, and include both governmental associations and parts of the federal government. For more information on the Smart Growth Network, its partners and membership program, and the annual New Partners for Smart Growth conference, visit www.smartgrowth.org.

Beyond Generic Parking Requirements

In calculating parking requirements, planners typically use generic standards that apply to individual land-use categories, such as residences, offices, and shopping. The most commonly used guidelines, issued by the Institute of Transportation Engineers in the Parking Generation Handbook (ITE, 2004), are based on observations of peak demand for parking at single-use developments in relatively low-density settings with little transit (Shoup, 2005). In such places, the destinations are widely separated, parking is typically free, and walking, biking, and transit are not available. As a result, planners assume in effect that every adult has a car, every employee drives to work, and every party visiting a restaurant arrives by car. Under these conditions, parking can take up more than 50 percent of the land used in a development (see figure). For more compact, mixed-use, walkable places, these standards end up calling for far more parking than is needed.

A surplus of parking really can be too much of a good thing. It creates a 'dead zone' of empty parking lots in the middle of what ought to be a bustling commercial district or neighborhood. This dead zone means there is less room for the offices and homes that would supply a steady stream of office workers and residents who might patronize businesses in the area -- and less room to cluster other businesses that will attract more foot traffic. Requiring more parking than the market actually demands adds substantial costs to development and redevelopment, and in some cases the added costs will prevent development altogether. For example, the future site of the D'Orsay Hotel in a prime location in Long Beach, California sat for years as a low-revenue parking lot -- every developer who considered building on it was stopped in part by the high cost of building a garage to fulfill the city's minimum parking requirement. It is under development today as a hotel and retail complex in large part because innovative strategies reduced the parking burden on the developer. See page 52 for the full case study.

Most planners surveyed relied on neighboring cities and national handbooks to determine parking requirements. This practice may result in inappropriate requirements if local conditions or policy approaches differ.

— Michael Kodama, Michael R. Kodama Planning Associates

Parking requirements are often copied from one jurisdiction to another, and so are remarkably consistent across different cities. Generic standards do not take into account the many highly local variables that influence parking, such as density, demographics, availability of public transit, potential for biking and walking, or the availability of other parking nearby. The obvious results of such rigid requirements are big empty parking lots -- and they can also result in empty buildings. Perfectly useable space in older buildings with limited or no on-site parking may prove unrentable, because the businesses that would like to locate there are unable to meet high minimum parking requirements. The buildings remain vacant, thwarting redevelopment plans (Shoup, 2005).

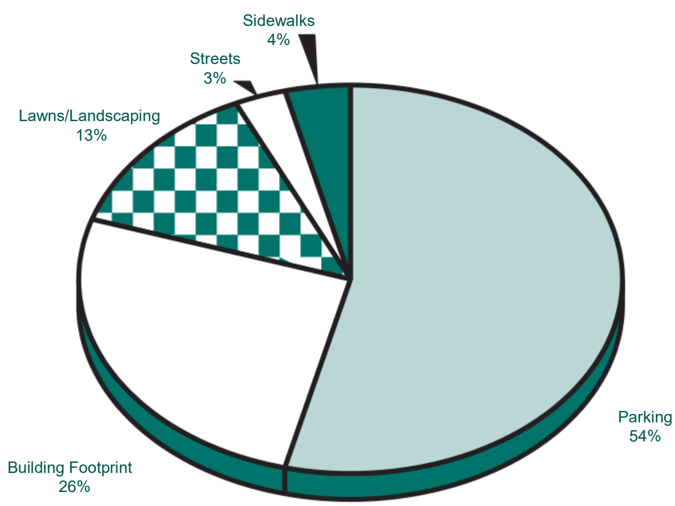
Generic parking standards have simply not kept up the complexity of modern mixed-use development and redevelopment. But parking requirements can be altered to allow planners to better measure the true demand for parking and to balance parking with wider community goals. This approach entails careful consideration of land-use and transportation characteristics that relate to parking demand. Successful examples consider the following factors.

- **Development type and size.** Take into account the specific characteristics of the project: is there a large theatre that requires evening parking, or will small shops attract short-term, daytime patronage? Can the two share parking spaces? Parking demand is of course also influenced by the size of the development, which is typically measured by total building square footage.

- **Development density and design.** Consider the density of the development. Research shows that each time residential density doubles, auto ownership falls by 32 to 40 percent (Holtzclaw et al. 2002). Higher densities mean that destinations are closer together, and more places can be reached on foot and by bicycle—reducing the need to own a car. Density is also closely associated with other factors that influence car ownership, such as the presence of good transit service, the community's ability to support stores located in neighborhoods, and even the walkability of neighborhood streets.

- **Demographics.** Consider the characteristics of the people using

Site Coverage for Typical Commercial Development
(averages for Olympia, Washington)



Source: City of Olympia Public Works Department, and the Washington State Department of Ecology, 1995.

In the process of establishing parking requirements, local communities are sometimes engaged in a balancing act. They must consider access, mobility, and traffic safety, but they also must encourage appropriate land use and traffic management, environmental protection, and energy and resource conservation.
— Thomas P. Smith
"Flexible Parking Requirements"
Planners Advisory Service Report 377

the development, including employees, customers, residents, and visitors. People of different incomes and ages tend to have different car ownership rates.

- **Availability of transportation choices.** Take into account the modes of transportation available to employees, visitors, and residents. Access to public transportation in a particular development, for example, can reduce parking demand. Walkable neighborhoods and bicycle amenities can also reduce parking demand.

- **Surrounding land-use mix.** Consider the neighboring land uses and density to better understand parking needs. For example, an office building parking lot will be empty when the restaurant next door is packed, so requiring both to provide for 100 percent of their parking needs simply wastes space.

- **Off-site parking.** Consider the parking that is already available near-by: on the street, on nearby properties, or in public garages that may be available for users of a new development. On-street parking can be considered to reduce the amount of on-site parking required for new development, or as a reserve should new uses require more parking than expected. On street parking has the added benefit of acting as a buffer between pedestrians and traffic, increasing the attractiveness of walking.

Land use and demographic information are important tools for establishing context-specific parking requirements that better balance supply and demand for parking.

The Costs of Parking

This section describes the costs of providing parking, both in terms of financial and environmental health. While parking is necessary, providing too much of it can exert a high cost, so understandings its impact is important. That impact can vary considerably with the amount and type of parking provided, and the types of development being served.

Financial Costs

The financial cost of providing parking is driven by three key factors: the number of parking spaces required, the 'opportunity cost' of the land used for parking, and the cost per parking space[1]. Parking requirements that assume suburban levels of demand in urban locations may necessitate large surface lots or parking garages, unnecessarily increasing the cost of infill and other compact development. The opportunity cost is the cost of using a space for parking instead of for a use with higher value. This varies considerably depending on the development context. In infill locations, the opportunity cost can be quite high, as each on-site parking space can reduce the number of new housing units or other users by 25 percent or more (Transportation and Land Use Coalition, 2002).

The cost per space depends on engineering and design considerations. Cost per parking space includes land, construction, maintenance, utilities, insurance, administrative, and operation costs (Tumlin and Siegman, 1993). The per-space costs tend to be higher in infill locations, providing a strong incentive for avoiding a parking surplus. Towns that are trying to encourage infill development or compact new suburbs can help spur those activities by accurately gauging parking demand. In general, the following factors affect the cost per space of parking:

- **Structured versus surface parking.** Parking garages are more costly to construct, operate, and maintain than surface parking lots, but can be desirable in urban locations seeking to create a more walkable environment. For example, Shoup (1998) reports construction costs of over $29,000 per space for a structured garage in Walnut Creek, California, against perhaps $2,000 per space to construct surface parking. Underground parking structures are more costly to construct than above-ground structures because of the added expense of excavation and required engineering.

Ignoring both the cost of providing parking spaces and the price charged for parking in them, urban planners thus set minimum parking requirements to satisfy maximum parking demand.

— Donald Shoup
Department of Urban Planning, UCLA

[1] All costs are updated to 2004 dollars. Costs include various components as noted. Where amortized, they assume a 7.5% interest rate over a 30-year period, and annual operating costs.

- **Land cost.** Land costs vary widely across settings (urban/suburban), geographic areas, and location within a particular city. Land costs in urban centers are generally much higher than in suburban areas. For example, in 1997 the cost per square foot of land in downtown Charlotte, North Carolina, was $121, while suburban land cost $21 (ULI, 1997). Higher land costs make the efficient supply and use of parking critical to development and redevelopment in urban areas.

- **Configuration and size of parking facility.** Parking structures and lots are more expensive to build and operate on smaller lots and complex land configurations, due in part to economies of scale. For example, smaller garages have higher costs per parking space because of the fixed capital costs (e.g., stairwells, ramps, and elevators) and fixed operating costs. These characteristics—smaller lots and more complex land configurations—are typical of urban areas, making parking more expensive at these locations.

- **Geologic conditions.** Parking structures on land with more sensitive seismic conditions or land with difficult terrain also cost more per parking space because they require more complex engineering and construction design. While geologic conditions vary across the country, developers have a greater choice of sites when considering development in suburban and rural areas. Sites in urban areas are more limited, and terrain with geologic constraints may be more difficult to avoid.

Land and construction costs, which account for most of the costs of parking, vary considerably across cities and parking designs. Construction costs alone also range widely due to building codes, materials, and labor costs, but per space construction costs for structures (above- or below-grade) are typically much higher than for surface lots. Willson (1995) expresses parking costs in terms of a monthly amount that would pay for the land, construction, and operating costs of providing a parking space. The reported monthly cost calculated for six surface parking sites in Southern California ranged from $50 to $110 per space, with an average of $86. The average cost for two sites in Southern California with above ground structured parking was $175 per space per month. Litman (2004) analyzes cost-recovery thresholds for parking under various scenarios, finding a range from $20 to nearly $200 per month to finance, build, operate, and maintain a parking space. With such wide variability, national averages, especially those including land costs, clearly do not have much meaning. This underlines the importance of looking at costs for a specific area when assessing potential savings from reducing oversupply.

Environmental Costs

In addition to tangible financial costs, parking has 'external' costs that affect the natural environment and the surrounding community, and these are typically not factored into development decisions. Parking lots and garages themselves have a direct impact on the environment, and they can affect the environment indirectly by cutting off transportation choices, encouraging driving that pollutes the environment.

Direct environmental impacts include: degraded water quality, stormwater management problems, exacerbated heat island effects, and excessive land consumption. Construction of surface parking often paves ground that once absorbed and filtered rainwater. This increases stormwater runoff, which can result in more flooding. The oil and other pollutants washed off the parking lot exacerbate water pollution. Dark pavement can artificially raise air temperature, resulting in 'heat islands' that raise air-conditioning bills. In undeveloped areas, forests, wetlands and other natural features should be considered part of a region's "green infrastructure" that process stormwater, clean the air, and provide wildlife habitat. Ensuring that parking areas are sized to a development's actual needs instead of to a generic requirement can preserve this infrastructure.

Parking also indirectly affects the environment, primarily because parking influences how and where people choose to travel. In conventional low-density, single-use development, the required large surface parking lots create places that are not friendly to pedestrians or transit. These places also require more and longer trips between homes, workplaces, schools, shops, and parks. As a result, people make the rational choice to drive almost everywhere -- and these areas register more vehicle miles of travel per capita. Increases in travel rates are associated with increased emissions of pollutants, including carbon monoxide and the pollutants that contribute to dangerous ground-level ozone. Air pollution is associated with asthma and many other health problems, driving up health-care costs.

Compact development that mix uses can reduce the need for surface parking, preserving green infrastructure while also reducing the amount of driving necessary for community residents. By creating an environment that supports the efficient use of parking, such development can also lead to better balance between parking needs and other community goals.

For further discussion of the environmental impact of development patterns, see *Our Built and Natural Environments: A Technical Review of the Interactions between Land Use, Transportation and Environmental Quality* (EPA, 2001a).

Innovative Parking Alternatives

As local governments respond to public demand for better development patterns, many have created alternatives to inflexible minimum parking requirements. The alternatives are aimed at avoiding an oversupply of parking, minimizing parking demand, or using the power of the marketplace to regulate parking. In areas of existing development, avoiding oversupply encourages better use of existing parking facilities and better evaluation of parking needs. Other policies give people an alternative to driving, and so reduce the demand for parking. And market-based pricing systems can help better match demand and supply, ensuring expensive parking spaces are used efficiently. Some of these strategies have lowered total development costs, further encouraging compact, mixed-use development patterns that moderate parking demand.

This section presents a selection of policies that make parking requirements more flexible. It includes a discussion of how and why these alternatives were developed, their advantages and limitations, and real-world examples. Each application has its own unique characteristics, and this diversity makes it impossible to isolate the costs and benefits of specific policies. The discussion presented here is not intended to portray any specific policy as universally applicable. Rather, community context should always be considered when balancing parking with other goals.

Strategies That Work

Parking Alternative	Example Location
Context-Specific Requirements	Montgomery County, Maryland Milwaukee, Wisconsin Los Angeles, California Eugene, Oregon Seattle, Washington Boston, Massachusetts
Centralized Parking, In-Lieu Fees	Miami, Florida Chattanooga, Tennessee West Palm Beach, Florida
Shared Parking	Long Beach, California Indianapolis, Indiana
Other Supply Strategies	Portland, Oregon Redmond, Washington Iowa City, Iowa
Land Banking and Landscape Reserves	Portland, Oregon Palo Alto, California Carmel, California Cleveland, Ohio Iowa City, Iowa
Car-Sharing	Boston, Massachusetts Washington, DC San Francisco, California Seattle, Washington Boulder, Colorado
Subsidies for Transit	Boulder, Colorado Santa Clara County, California San Bernardino County, California Montgomery County, Maryland
Transit Improvements	Portland, Oregon Chattanooga, Tennessee
Pedestrian and Bicycle Facilities	Schaumburg, Illinois Kendall, Florida
Transportation Demand Management Programs	Cambridge, Massachusetts Seattle, Washington Montgomery County, Maryland
Pricing Strategies	Los Angeles, California Santa Monica, California San Diego, California Pasadena, California

Reduce Oversupply

As discussed earlier, in communities working to create mixed-use, compact, walkable places, inflexible application of conventional minimum parking requirements tends to create an oversupply of parking. This creates unnecessary environmental impacts and financial costs. The strategies discussed below can reduce the supply of parking while still effectively meeting demand.

Context-Specific Standards

Setting parking standards to fit the particular context of a neighborhood or development is a challenge planners are just beginning to tackle. As discussed earlier, parking requirements are often applied for each land use city wide, and so lack the flexibility needed to address different parking needs.

A major challenge for city planners is how to make codes more flexible and sensitive to specific local conditions, but still provide the predictability desired by developers. Codifying reductions in parking requirements provides the greatest certainty for governments, citizens and neighbors, and developers, and enables all to plan for balancing parking with other development goals. When the reductions in parking requirements are clearly stated in the codes, developments are less likely to be held up in the permitting process or challenged by local residents. Planners need to develop an understanding of local parking markets, combine this with experience from other settings, and then create local parking requirements. Some of the mechanisms being used are:

- **Transit zoning overlays.** In areas with frequent transit service, especially those served by rail stations, fewer residents, workers, and shoppers require parking. In addition, the density and mix of uses possible around rail stations can sometimes support market-rate parking, which leads to more efficient use. Many cities find they can reduce minimum parking requirements for certain uses that are within a specified distance of a rail station or frequent bus route. For example, Montgomery County, Maryland reduces parking requirements by as much as 20 percent, depending on distance from a Metrorail station. Parking are only one aspect of transit zoning overlays, which often address issues such as density, design, and allowable uses. Codes may encourage shared parking in transit zones, which accommodates more cars than parking reserved solely for residents and commuters.

Location- and Use-Specific Requirements

Milwaukee, Wisconsin

Milwaukee has some of the lowest city wide parking ratios anywhere in the country. Parking ratios for retail are two spaces per 1,000 square feet, compared to the Institute of Transportation Engineers' standard of one to 300 square feet. For business uses, Milwaukee requires eight spaces for the first 2,000 square feet, and one for each subsequent 1,000 square feet. In the downtown zone, there are no minimum parking requirements for any land use except high-density housing, where the ratio is a very low two spaces per three units. The city generally discourages surface lots within the downtown and dictates that at least 50 percent of the ground floor of parking structures be used for retail.

These policies were enacted in 1986 and strengthened in October 2002 with new credits for transit-oriented development, on-street parking, and shared parking. Developments within a defined geographical area near transit (which encompasses over half of the city area) are granted reductions of up to 15 percent in the minimum requirements. Further reductions are allowed for on-street spaces adjacent to the property (up to a 1:1 space credit), and for shared parking (up to 0.75 space credit for each shared space). One to one credits are also allowed for leased parking spaces in existing lots within 750 feet of the site.

Source: Milwaukee Department of City Development, 2002.

- **New zoning districts or**

specific plans. In compact, mixed-use, walkable neighborhoods and town centers parking requirements can frequently be lower than typical minimum requirements. Some communities have adopted designated zoning districts or neighborhood specific plans to accomplish this. Most commonly, this applies to the downtown; Milwaukee finds that parking and other goals can be met with lower parking requirements than in outlying locations. Some areas waive the minimums altogether, letting the development market decide where and how to build parking. The same techniques can be applied to neighborhoods outside of downtowns that offer frequent transit, such as Seattle's Pike/Pine district. Specific plans, which detail development requirements at the parcel level, are particularly useful to encourage infill development in older neighborhoods or on brownfield sites.

Location- and Use-Specific Requirements

Seattle, Washington

Seattle's zoning code grants reductions in minimum parking requirements based on several factors, including:

- Affordable housing. Minimum parking requirements are reduced to between 0.5 and 1.0 space per unit, depending on income, location, and size of unit.
- Senior housing and housing for people with disabilities.
- Car-sharing. Only for multi-family developments that allow dedicated on-site parking for the city's recognized car-sharing operator.
- Location. No parking minimums are set for downtown and they are reduced in mixed-use, dense neighborhoods.\

Source: Seattle Department of Transportation, 2001.

- **Parking freezes.** The amount of parking required can be directly reduced through parking freezes that cap the total number of parking spaces in a particular metropolitan district. . Cities with successful parking freezes generally have strong economies and well developed transit systems, and are attractive to tenants, customers, and visitors. Such cities can attract businesses because the benefits of the urban location outweigh the potential drawback of limited parking, and because public transit offers a viable alternative to automobile use. Downtown Boston has had a parking freeze in effect for many years in an effort to control driving and the associated emissions. Downtown San Francisco has applied a cap on commuter parking, as their downtown street network functions at capacity during rush hours, and transit and other travel options are numerous. Jurisdictions using the restrictions generally view each new parking space (commuter spaces in particular) as the generator of one more rush-hour vehicle trip, and want to limit those trips to reduce air pollution and congestion.

- **Reductions for affordable and senior housing.** Successful regions frequently struggle to provide affordable housing, as desirability and supply drive up housing prices. In many of these places, providing housing to lower-income workers and senior citizens can become an important goal. Since people with lower incomes and older people tend to own fewer vehicles parking requirements can be reduced for below-market-rate units and senior housing. This reduces the overall cost of providing such housing, and may increase the number of units that can be provided. Los Angeles grants a reduction of 0.5 spaces per unit for deed-restricted affordable housing units, with further reductions if they are within 1,500 feet of mass transit or a major bus line.

- **Case-by-case evaluation.** Where area-wide or systematic code changes are not possible, reductions in parking requirements can be granted on a case-by-case basis, often on the condition that mitigation measures such as car-sharing (see page 23) are provided. Cities such as Eugene, Oregon specify in their zoning codes that such reductions will be granted subject to a parking study showing that the proposed provision will be adequate to meet demand.
- **Abolish requirements.** Another approach is for cities to simply abolish all parking requirements in neighborhoods that are served by a range of travel options and where surrounding residential areas are protected from spillover parking from other users (Millard-Ball, 2002). This leaves it up to developers—who have a financial interest in meeting tenants' needs while not oversupplying parking—to determine how many spaces are needed.

Maximum Limits and Transferable Parking Entitlements

Maximum limits turn conventional parking requirements upside down by restricting the total number of spaces that can be constructed. Planners set maximum limits much as they set minimum requirements. Typically, a maximum number of spaces is based on the square footage of a specific land use. For example, Portland, Oregon, allows buildings in the central business district a maximum of 0.7 parking spaces per 1,000 square feet of office space, and 1.0 space per 1,000 square feet of net building area for retail.

The generous parking capacity required by planners often goes unused. Studying office buildings in ten California cities, Richard Willson (1995) found that the peak parking demand averaged only 56 percent of capacity.

— Donald Shoup, UCLA

Communities can make maximum parking requirements more flexible by introducing transferable parking entitlements, as in Portland Oregon. The allowed number of parking spaces for a particular development are an "entitlement" that can be transferred or sold to another development if they are unused. This policy enables cities to control the parking supply, without restricting developments that would not be feasible without additional parking. Projects that require more parking can proceed, while those that need less parking can benefit by selling their rights, or negotiating shared parking agreements for their employees or customers.

Portland's planners are using parking maximums in an attempt to "improve mobility, promote the use of alternative modes, support existing and new economic development, maintain air quality, and enhance the urban form of the Central City" (City of Portland, 1999). By combining maximums with transferable parking entitlements, Portland's downtown provides ample parking for retail and other priority uses, along with market-rate commuter parking, in a compact, walkable area with a mix of uses and transportation choices.

Both planners and developers benefit from restricting the number of parking spaces allowed. From the city's perspective, maximum limits:

- Improve the urban environment by preserving open space and limiting impervious surfaces;
- Reduce congestion;
- Encourage attractive, pedestrian-friendly urban design; and
- Promote transportation choices.

From the developer's perspective, maximum limits:

- Minimize costs for parking construction, operations, and maintenance;
- Reduce traffic and traffic-related costs; and
- Allow development at a greater floor-to-area ratio, increasing leasable space.

There are challenges to setting and maintaining maximum limits. Planners must consider possible spillover parking in surrounding residential neighborhoods if parking in those areas is free.. To avoid such spillover, developers must understand the factors that affect parking demand and ensure that viable transportation choices exist. A common policy for preventing parking spillover into residential areas is to implement residential parking permit programs, but these have drawbacks (see discussion of parking benefit districts on page 33). Changes in frequency or routing of transit, increases or decreases in development densities, or changes in land use can all influence the demand for parking in the neighborhood.

Linking Maximum Limits and Transit Improvements

Portland, Oregon

In Portland, Oregon, maximum parking limits vary according to distance from light rail stations. For example, new office space on the light rail transit mall is allowed 0.8 spaces per 1,000 square feet, while office space in Goose Hollow, located several blocks from the transit mall, is allowed 2.0 spaces per 1,000 square feet.

These maximum limits have not been problematic to developers. In fact, property values and customer volume in the parking-restricted areas near transit stations are higher than in other areas. In a 1987 survey of 54 businesses located near light rail transit, 66 percent of business owners said that their businesses had been helped because they were located near public transit; 54 percent reported increased sales volumes as a result of being located near transit, in spite of reduced parking supply.

Source: Tri-County Metropolitan Transportation District of Oregon, 1999.

With restrictive maximum limits on the number of parking spaces, developers may worry about the long-term marketability of a property. Marketability should not be a concern for competing developments in the same locale if all developments must adhere to the maximum limits. Parking restrictions that may seem to place urban areas at a disadvantage can be offset by amenities other than parking, such as convenient access to services and places of employment, attractive streetscapes, or pedestrian-friendly neighborhoods. City governments and developers should incorporate these elements to attract businesses and residents. Maximum requirements are not ideal for all locations. Municipalities that employ maximum requirements must have accompanying accessible and frequent public transportation. It is also important for the area to be sufficiently stable economically to attract tenants without needing to provide a surplus of parking. A number of cities have implemented maximum parking requirements, including San Francisco and Seattle.

Shared Parking

The concept of shared parking is based on the simple idea that different destinations attract customers, workers, and visitors during different times of day. An office that has peak parking demand during the daytime, for example, can share the same pool of parking spaces with a restaurant whose demand peaks in the evening. The first shared parking programs arose when developers, interested in reducing development costs, successfully argued that they could accommodate all demand on site with a reduced number of spaces. The Urban Land Institute (ULI) report *Shared Parking* (2005) presented analytic methods for local governments and developers to use on specific projects, and as mixed-use projects continue to grow in number and sophistication, ULI continues to update this methodology.

By allowing for and encouraging shared parking, planners can decrease the total number of spaces required for mixed-use developments or single-use developments in mixed-use areas. Developers benefit, not only from the decreased cost of development, but also from the "captive markets" stemming from mixed-use development. For example, office employees are a captive market for business lunches at restaurants in mixed-use developments.

Shared parking also allows for more efficient use of land and better urban design, including walkability and traffic flow. Shared parking encourages use of centralized parking lots or garages and discourages the development of many scattered small facilities. A sidewalk with fewer driveway interruptions and more shop fronts is more comfortable and interesting for pedestrians and will encourage walking. Reducing driveways also results in more efficient traffic flow because there are fewer turning opportunities on main thoroughfares. This has the added benefits of reducing accidents and reducing emissions from idling vehicles stuck in traffic.

Establishing shared parking requirements involves

Shared Parking

Circle Centre — Indianapolis, Indiana

Opened in September 1995, Circle Centre in Indianapolis' central business district offers retail and entertainment destinations. This development contains 630,600 square feet of retail space and100,000 square feet of restaurant, speciality, and entertainment space, as well as a 2,700-seat cinema. One of the factors that led to the financial success of this $300 million project was a shared parking arrangement that saved money and allowed a pedestrian-friendly design.

Under generic minimum parking requirements, Circle Centre would have needed about 6,000 parking spaces. By using shared parking, the project was built with just 2,815 spaces. Shared parking for Circle Centre is used for both customers and employees. The mixed-use nature of the development project allows customers to use a single parking space for multiple destinations within the complex. Employees can use nearby off-site parking, particularly in evenings and on weekends when more than 12,000 nearby off-site spaces that normally serve downtown office workers become available. Taking these two shared parking components into account decreases the estimated need for on-site parking by more than 50 percent.

This reduction in parking demand translates into considerable cost savings. At parking costs of about $10,000 per space for aboveground structured parking, development costs were reduced by about $30 million.. In addition, operating costs were reduced by approximately $1 million per year.

Source: Smith, 1996.

site-specific assessment or use of time-of-day parking utilization curves, which were developed by the ULI in *Shared Parking.* Planners need to consider several factors when developing shared parking requirements, including the physical layout of the development; the number of spaces for each of the individual land uses; the types of parking users (e.g., employees, residents, or hotel guests who park all day, or customers and visitors who park for short periods of time); and hourly accumulation of parking for each land use.

Montgomery County, Maryland, allows for shared parking to meet minimum parking requirements when any land or building under the same ownership or under a joint-use agreement is used for two or more purposes. The county's ordinance also allows parking reductions based on proximity to transit, participation in TDM programs, or location in the central business district. The county uses the following method to determine shared requirements for mixed-use developments:

Calculating Parking for Mixed-Use Developments
(Montgomery County, Maryland)

	Weekday		Weekend		Nighttime
	Daytime (9 a.m. - 4 p.m.)	Evening (6 p.m. - 12 a.m.)	Daytime (9 a.m. - 4 p.m.)	Evening (6 p.m. - 12 a.m.)	(12 a.m. - 6 a.m.)
Office	300*	30	30	15	15
Retail	168	252	280*	196	14
Entertainment	40	100*	80	100*	10
TOTAL	**508**	382	390	311	39

* Peak demand by use.
Source: Smith 1983, page 7.

- Determine the minimum amount of parking required for each land use as though it were a separate use, by time period;
- Calculate the total parking required across uses for each time period; then
- Set the requirement at the maximum total across time periods.

The table above illustrates how peak demand occurs at different times of the day and week for different land uses. While maximum parking demand for the office component of the project occurs during the daytime on weekdays, maximum demand for retail occurs during the daytime on weekends, and peak entertainment demand is in the evening. For this example, setting parking requirements using maximum demand would have resulted in requiring 680 spaces (300 spaces for office, 280 spaces for retail, and 100 spaces for entertainment). By recognizing the shared parking potential, the developer cut almost 200 unnecessary parking spaces (about 25 percent), representing a considerable cost savings.

An American Planning Association report, *Flexible Parking Requirements*, highlights factors that facilitate shared parking (Smith, 1983). The report suggests that for shared parking to function effectively, parking requirements for individual land uses must reflect peak-demand land use and common parking facilities must be near one another. Parking spaces should not be reserved for individuals or groups.

Centralized Parking
Chattanooga, Tennessee

To encourage urban development in downtown Chattanooga while limiting congestion and air pollution, the Chattanooga Area Regional Transit Authority (CARTA) developed a strategy to provide peripheral parking and a free shuttle service. The system is designed for the city's linear central business district and allows workers and visitors to drive to the city, park in one of the two peripheral garages, and use the shuttles to travel up and down the 15-block business corridor. By constructing parking at either end of the business district, CARTA intercepts commuters and visitors before they drive into and through the city center, reducing traffic congestion.

The two parking garages Shuttle Park South (550 spaces) and Shuttle Park North (650 spaces), are owned by CARTA and operated privately. The free shuttle buses are financed through the garages' parking revenues. They depart from each garage every five minutes all day, every day, and pass within walking distance of most downtown destinations.

The electric-powered shuttles transport approximately one million riders each year, making shuttle-served property attractive to businesses. Since 1992, when the shuttle service began, over $400 million has been spent on development in Chattanooga, including the successful aquarium, over 100 retail shops and over 60 restaurants. CARTA's initiatives won commendation from EPA, receiving a "Way to Go" award in 1996 for innovative transportation solutions that support urban development.

Sources: EPA, 1998; Chattanooga News Bureau, 1999.

Centralized Parking Facilities and Management

A subset of shared parking is the construction of centralized parking lots and garages. Some cities mandate centralized parking facilities and finance them through development impact fees, in lieu parking fees, or negotiated contributions established during the environmental review process. Centralized parking can be built and operated by a public entity or public/private partnership and reduce the costs of parking because large facilities are less expensive on a per space basis to build and maintain than small facilities. The example in the next chapter of Wilton Manors, Florida, is such a case.

Centralized parking facilities can meet urban design goals if they allow the elimination of small surface parking lots and driveways that interrupt the walkable fabric of mixed-use areas. Centralized parking enables travelers to park once to visit several destinations, potentially reducing on-street congestion from short trips within an area. Developers are sometimes concerned that centralized parking will be inconvenient for building occupants, but these concerns can be addressed in part by building several "centralized" facilities throughout a business district or mixed-use area. Centralized management can still ensure coordinated policies for their use, maintaining many of the advantages of centralized parking. In other cases, the operator can provide shuttle services to and from centralized garages. Many downtown areas have successfully instituted centralized parking. Some cities, such as Pittsburgh and Chattanooga (see box) operate such facilities at the periphery of the downtown, reducing traffic and mobile source emissions in the core and freeing up land in the center city for other development.

In-Lieu Parking Fees

In-lieu parking fees are one way to finance such centralized public garages and give developers flexibility in providing parking on-site. Developers are able to avoid constructing parking on site by paying the city a fee, and the city in return provides off-site parking that is available for use by the development's tenants and visitors. The city determines the fees, generally based on the cost of providing parking.

Cities set fees in one of two ways, either by calculating a flat fee for parking spaces not provided by a developer on site, or by establishing development-specific fees on a case-by-case basis. Shoup (2005) reports that in-lieu fees in the United States range from $2,000 to $20,000 per parking space and may or may not reflect the true costs of providing parking. These fees can be imposed as a property tax surcharge or at the time of development permitting.

In-lieu parking fees provide a mechanism for providing parking in balance with other community goals, satisfying the public as well as planners and developers. Using in-lieu fees and centralized garages can:

- Reduce overall construction costs;
- Avoid construction of awkward, unattractive on-site parking that could compromise historic buildings;
- Increase public access to convenient parking;
- Ensure that parking facilities will be used more efficiently; and
- Encourage better urban design with streetscapes uninterrupted by parking lots and driveways.

In establishing in-lieu parking fees, planners must be aware of potential developers' concerns that the lack of on-site parking will make developments less attractive to tenants and visitors. This can be an issue if available public parking is insufficient, inconveniently located, or inefficiently operated. Planners must carefully consider the parking demand for each participating property and provide enough parking to meet this demand in order to avoid creating a perceived or real parking shortage. Planners must also work to ensure that public parking facilities are located and operated in ways that support development.

In-Lieu Parking Fees

Coconut Grove — Miami, Florida

Coconut Grove is a pedestrian-oriented, entertainment, dining, and shopping village in southern Miami. To maintain Coconut Grove's continuous street frontage and keep it attractive to pedestrians, city planners established flexible parking requirements. Developers or property owners have three choices for satisfying minimum parking requirements: they can provide off-street parking, contract spaces elsewhere, or pay in-lieu fees. With little space left to develop and high land costs, most property owners choose to pay the $50 per space per month fee to the city and use the land for more productive, revenue-generating purposes. The city uses the in-lieu fees to provide shared, structured parking, improve transit service, and maintain the sidewalks and pedestrian amenities. By investing the in-lieu fees in a combination of parking and other improvements, the city helps to keep Coconut Grove walkable and maintain the attractive aesthetic character of the area.

Source: Coconut Grove Chamber of Commerce.

Accounting for Uncertainty

Estimating parking demand is not an exact science, and a few communities are setting aside land through land banking and landscape reserves that can be converted into parking if shortages arise. Landscaping can often be used to turn this set-aside land into an attractive amenity for the development or wider community, but requiring new development to purchase additional land as insurance against uncertain parking demand imposes additional costs, which may work against community redevelopment goals.

Land banking and landscape reserves are particularly useful policies when the expected need for off-street parking for a particular use is uncertain, due to unknown or unusual operating characteristics, or if no data is available to establish need. Cities could respond by requiring the construction of parking spaces that may well sit empty. But these techniques allow supply to be determined by the best estimates, with the security that more parking can be constructed if needed. In some cases, landscape reserves can be required in conjunction with parking reductions granted in return for company plans to reduce private vehicle trips, known as Transportation Demand Management (TDM) plans. If the employer falls out of compliance with the TDM plan, they can be required to go to the expense of constructing additional parking.

Land Banking

Iowa City, Iowa, and Palo Alto, California

Both Iowa City and Palo Alto have enacted land-banking policies in their parking codes. In some neighborhood commercial zones in Iowa City, minimum parking requirements may be waived or relaxed, and land banking used in place of up to 30 percent of the otherwise required parking. If an enforcement official determines in the future that the additional parking spaces are needed, the property owner can be required to construct parking on the land banked area.

Palo Alto's code authorizes the city to defer up to 50 percent of the required spaces as a landscape reserve where the expected need for off-street parking for a particular development is uncertain. The California Park Apartments development, for example, was allowed to defer 22 of the 95 parking spaces required by city code, using the land instead for a family play lot, a barbeque area, and picnic benches. Nearly 15 years after construction, the landscape reserve has not been needed for parking, and the community enjoys the environmental and social benefits of the recreation area.

Source: Iowa City and Palo Alto Zoning and Parking Codes.

Land banking and landscape reserve policies have been implemented in cities throughout Oregon (including Portland), as well as Palo Alto, California; Carmel, California; Cleveland; and Iowa City, Iowa. Palo Alto allows reductions of up to 50 percent in minimum parking requirements, provided that the difference is made up through a landscape reserve. None of the city's landscaped reserves have subsequently been required for parking.

To avoid confusion with terminology, it should be noted that land banking can also refer to the purchase of land by a local government or developer for use or resale at a later date. Banked land is sometimes used as interim parking to generate revenue generation—parking fees from temporary lots are put towards construction of later phases of the development, and at some point built over into buildings or structured parking.

Manage Demand

While reducing excess parking supply is important in eliminating the waste of unused parking spaces, some communities are looking to directly reduce the demand for parking, by providing people with readily available alternatives to driving. Demand reduction programs include car sharing, subsidies for transit, transit improvements, pedestrian and bicycle facilities, and comprehensive vehicle trip reduction programs that may include telecommuting and/or flexible work schedules to reduce commuting. While these programs are typically developed by local governments, their success often depends on the commitment of businesses to implement them effectively.

Car-Sharing

Car-sharing is a neighborhood-based, short-term vehicle rental service that makes cars easily available to residents on a pay-per-use basis. Members have access to a common fleet of vehicles, parked throughout neighborhoods so they are within easy walking distance, or at transit stations. In programs with the most advanced technology, members simply reserve the nearest car via telephone or the Internet, walk to its reserved space, open the door using an electronic card, and drive off. They are billed at the end of the month, gaining most of the benefits of a private car without the costs and responsibilities of ownership, and without having to search for parking when their trip is over.

In urban neighborhoods with good transit access, car-sharing can eliminate the need to own a vehicle, particularly a second or third car that is driven less than 10,000 miles per year. In San Francisco, nearly 60 percent of households that owned vehicles before joining the car-sharing program have given up at least one of them within a year, and another 13 percent were considering it (Nelson\Nygaard, 2002). Zipcar, which operates in Boston, New York, and Washington, DC, reports that 15 percent of members sell their private car. In Europe, which has a far longer experience with car-sharing, each shared vehicle takes between four and ten private cars off the road -- and out of city parking spaces (City of Bremen, 2002).

In some cities, developers have been allowed to reduce the number of parking spaces if they incorporate car-sharing. Developers may need to contribute towards set-up costs and/or provide parking spaces reserved for car-sharing vehicles as part of a project. Car-sharing can be provided as part of a mitigation agreement with the local jurisdiction in return for a reduction in minimum parking requirements. Alternatively, the parking reduction can be codified through zoning ordinances, as is being considered in Portland, Oregon, San Francisco, and Seattle.

Car-Sharing, Pricing Strategies

Van Ness and Turk Development -- San Francisco, California

This development includes 141 residential units in a dense area of San Francisco, with only 51 parking spaces. The development was granted a substantial reduction in parking requirements—nearly two-thirds—from the city's minimum of 1 space per unit, to 1 space per 2.8 units. The reduction was granted in large part because of the developers' agreement to provide two parking spaces for car-sharing operator City CarShare, accessible to residents and all CarShare members. Strong community and organizational support, as well as proximity to major transit corridors, were also factors.

If the developers had been required to build the additional 90 spaces required by code, they would have been forced to add either subterranean levels or parking lifts, which save space by stacking vehicles on top of each other. These expensive options would have cost between $1.35 million for lift technology (estimated at $15,000 per space) or $8.1 million for additional below-grade parking levels (estimated at $60,000 to $90,000 per space).

The developer also "unbundled," parking costs, so that residents are charged for parking separately from rent. The current market rate for parking is $280 to $300 per space per month. By charging separately for parking and incurring lower construction costs, the developer is able to keep apartment rents lower.

Source: Thieophilos Developers, 2002.

Car-sharing can also be a useful tool to reduce parking demand in commercial developments. Employees can use a shared vehicle for meetings and errands during the workday, allowing them to take transit, carpool, walk, or bicycle to work. Car-sharing works best in compact, mixed-use neighborhoods, where firms with corporate memberships tend to use the vehicles during the day and residents can use them in the evenings and on weekends.

Formal car-sharing programs have been established in many cities, including Boston; Washington, DC; San Francisco; Oakland, California; Portland, Oregon; Seattle; and Boulder, Colorado, and are being established in many others. Some programs are run by non-profits with significant government support. Private for-profit companies, notably Flexcar and Zipcar, are operating in a number of cities, but they often work with the city or the local transit agency to secure reserved parking spaces on city streets or in transit park-and-ride lots. Alternatively, developers can provide shared vehicles themselves, or facilitate informal car-sharing among residents. Car-sharing reduces parking demand, but it also brings a broad range of other benefits, including fewer vehicle trips with less associated pollution, and improved mobility for low-income households who may not be able to afford to own a car, if rental rates are low enough..

Incentives for Transit

Financial incentives to ride transit can help reduce parking demand. They can be provided by employers, by cities, or by residential property managers.

Car-Sharing, Parking Maximums

Rich Sorro Commons -- San Francisco, California

Plans for Mission Bay, a 303-acre brownfield redevelopment area in San Francisco, include 6,000 units of housing, office space, university facilities, a hotel, community services, and retail. The city introduced parking maximums in this area to maximize the amount of new housing, make the most of the new Third Street Light Rail line through the neighborhood, and minimize traffic impacts on congested streets and the nearby freeway. Residential parking maximums were set at one space per unit.

One of the first projects completed was Rich Sorro Commons, a mixed-use project with 100 affordable units and approximately 10,000 square feet of ground floor retail. It was constructed with only 85 parking spaces, due to:

- Excellent proximity to light rail, commuter rail, and frequent bus service;
- Provision of two parking spaces for City CarShare; and
- Units below market rate, with tenants who are less likely to own a car.

With fewer parking spaces, Rich Sorro Commons was able to make space available for a childcare center and retail stores at ground level. The 17 would-be parking spaces were converted to retail space that is expected to generate revenues of $132,000 annually for the project (300 square feet per space at $25.80 per square foot in rent), making housing more affordable. The two City CarShare vehicles are available to residents, giving them access to a car without the costs of ownership – a particularly important benefit for low-income households.

Source: Kenneth Jones, Developer, 2002.

In the case of employer-paid transit pass plans, the employer pays the cost of employees' transit, often instead of providing a free parking space. This fringe benefit for employees reduces the demand for parking at the workplace, which in turn reduces traffic, air pollution, and energy consumption. It can equalize the transportation benefit that traditionally only went to employees who drove to work and received a free parking space. It also reduces costs, as transit benefits are generally less expensive to employers than providing parking. A transit pass in Los Angeles, for example, costs $42 per month, whereas the average cost for a parking space is $91 per month (Shoup, 1997b). To promote transit subsidies, the 1998 Transportation Equity Act for the 21st Century changed federal law so that transit benefits are not counted as payroll or as income (see also the description of cash-out programs on page 31). In some cases, city planners respond to employer-paid transit benefits by lowering minimum parking requirements. For example Montgomery County, Maryland's office zoning requirements allows a 15 percent reduction in minimum parking requirements if businesses offer reimbursed transit passes (Smith, 1983). The reduction in required parking can make urban development opportunities more inviting.

Transit incentives can also be useful for residential developments, or even for neighborhoods.. Property managers in Boulder, Colorado, and Santa Clara County, California, for example, can bulk-purchase transit passes for all their

Courtesy of City Car Share

residents at deeply discounted rates. The principle is similar to that of insurance—transit agencies can offer lower rates on passes because not all residents will actually use them regularly. Residents can take transit for free, meaning they are less likely to own a vehicle. Another benefit of prepaid transit programs is that they encourage residents to take transit spontaneously, since costs are paid up-front. A person does not have to commit to transit full-time in order to be able to reduce their demand for vehicle travel and parking. Developers who agree to fund transit passes can thus be rewarded with lower parking requirements.

Using Parking Revenue to Support Transit

Boulder, Colorado

Faced with a shortage of parking for customers, Boulder developed a program to encourage downtown employees to commute by other means. In 1993, Boulder's City Council mandated restricted downtown parking and appealed for parking demand management for the city's commuters.

The Central Area General Improvement District (CAGID), made up of many of downtown's 700 businesses, responded to the Boulder City Council's demands by creating a system using revenue from downtown parking meters to pay for free bus passes. The passes are provided for all of the district's 7,500 employees, and cost $500,000 each year The program has changed travel behavior, freeing up valuable customer parking spaces:

- Employee carpooling increased from 35 percent in 1993 to 47 percent in 1997.
- The district's employees require 850 fewer parking spaces.
- The increase in available parking has encouraged more retail customers to shop in downtown Boulder.

Boulder has created a special website with information about parking issues in the region: http://boulderparking.com.

The City of Boulder offers deeply discounted Eco-Passes to businesses outside the CAGID and to residents, and encourages walking and bicyccling. These programs mean Boulder employees avoid 212,500 single-occupancy vehicle trips per year, saving an estimated two million miles of pollution- and congestion-causing automobile trips. use is prevented each year.

Source : Boulder Community Network, 1999.

Transit Improvements

One of the best ways to reduce the demand for parking is to improve transit service so that it is frequent, convenient, and easy to use. Local government officials can improve public transit through major projects, such as adding light rail lines or streetcars, or creating systems that give buses priority at lights and intersections. They can also lengthen transit service hours, increase the frequency of bus and train service, and revitalize transit stations. Small improvements can also help, such as convenient SmartCard payment systems, improved bus stops and shelters, and real-time directional and schedule information systems. Portland, Oregon's MAX light rail system exemplifies the widespread benefits of transit improvements. The light rail system encourages transit-oriented development, decreases automobile commuting, and eases demand for parking. In fact, the light rail improvements eliminated the need for six downtown parking towers (EPA, 1998). These improvements are also partially responsible for $1.3 billion in new development in Portland over the last 10 years.

Pedestrian and Bicycle Facilities

Demand for parking can be reduced by providing pedestrian and bicycle facilities and amenities that make it easier and more pleasant for people to walk or bicycle to work, on errands, or to lunch. These changes can alleviate traffic congestion; for example, the automobile-dependent design of Tyson's Corner, Virginia, has resulted in high volumes of traffic at lunch time because people cannot walk to restaurants or to run errands.

Promoting bicycling and walking can be accomplished through both comprehensive policies and simple changes to the street.. Some jurisdictions have adopted 'complete streets' policies that require every road construction or improvement project to provide safe access for everyone using the road, including transit users, bicyclists, and pedestrians (see www.completestreets.org). Other communities have focused on closing gaps in the sidewalk or bikeway network, by adding sections of sidewalks, bike lanes, or multi-use paths where needed to ensure safe travel by those modes.

In addition to paying attention to the street, bicycling and walking can be encouraged through design changes that make walking and bicycling more secure and pleasant. The Downtown Master Plan for Kendall, Florida (Miami-Dade County), discusses several design concepts to improve pedestrian and bicycle access. Some of the key elements promoted, but not required, by this program are listed in the text box to the right.

Developers can also encourage bicycling and walking by providing on-site facilities such as bicycle racks and even lockers and showers. For example, officials in Schaumburg, Illinois, a suburb of Chicago, have incorporated provisions into their zoning ordinance to encourage bicycle use. The ordinance requires all retail centers to have a minimum of 10 bicycle spaces located at each main building entrance. To increase awareness, the ordinance requires that bike racks be highly visible; to protect bicyclists, the ordinance requires bicycle parking areas to be separated from automobile parking. Other jurisdictions require covered, secure bicycle parking for employees who will be leaving their bicycles all day.

Designing for Pedestrians

Kendall, Florida

Close attention to design can dramatically improve the environment for pedestrians. The city of Kendall, Florida, has started to redevelop a conventional mall near a rail station into a new town center. The Downtown Master Plan specifies a number of improvements to create a compact, walkable place with good connections to existing neighborhoods:

- Bicycle/pedestrian access via new sidewalks and pathways.
- Trees and shrubs along edges facing streets and sidewalks.
- Parking hidden in the rear or in parking garages.
- Shade and rain protection for pedestrians, such as colonnades, arcades, marquees, second-floor balconies, wide awnings, or tree canopies.
- Buildings positioned along the sidewalks at a deliberate alignment, giving a designed shape to the public space.
- Doors and windows spaced at close intervals to generate activity, direct views to merchandise, and make walking interesting.
- Minimal number of driveways and parking lot entries that can making walking unsafe and erode urban space.

Source: Downtown Master Plan, Kendall, Florida, 1998.

Travel Demand Management (TDM) Programs

Travel demand management (TDM) programs combine several trip-reduction strategies to meet explicit travel goals. Some TDM programs are put into place by a single employer; others are managed by governments or business improvement districts and focus on a developed area that may include both businesses and homes. These programs typically attempt to decrease the number of trips by single-occupant vehicles, sometimes setting goals such as reduced vehicle trips or reduced miles traveled, while increasing the use of a variety of commuting and travel alternatives, including transit, carpooling, walking, and bicycling. TDM plans can be used by city planners to allow developers to build fewer parking spaces.

TDM programs may encourage transit incentives, parking cash-out, and other strategies mentioned here. In addition, these programs typically incorporate an assortment of complementary program elements that make it easier for people to give up solo driving. Examples include:

- "Guaranteed ride home" services that allow employees who use public transit to get a free ride home (usually via taxi) if they miss their bus or if they need to stay at work late.
- Company fleet cars that can be used for business meetings or running errands during the workday
- Preferential and/or reserved parking for vanpools/carpools.
- Carpooling and/or vanpooling with ride-matching service. Ride matching through informal "ride boards" or an employee transportation coordinator, helps people find and form carpools with neighbors.
- Cell phones for carpoolers to facilitate timing of pick-ups.

Shared Parking, Transit Improvements, TDM Program

Lindbergh City Center -- Atlanta, Georgia

The Lindbergh City Center is a mixed-use, high-density development in Atlanta on property owned by the transit agency, MARTA. The project was envisioned with a goal of having transit carry 30 percent of all trips to and from the center. The development, which includes a hotel and restaurant as well as office, retail, and residential space, centers on a MARTA light rail station that connects it to downtown Atlanta, the airport, and other areas. Parking reductions were allowed because of shared parking between office and retail uses, because of the ample transit access, and as a result of the Transportation Demand Management programs. Parking requirements for the first phase of the development were reduced by 20 percent overall; for office space the reduction is as high as 70 percent. Condominiums are allowed an 8 percent reduction, from 2 to 1.85 spaces per unit.

Source: Paul Vespermann, Lindbergh City Center, 2002.

Employers have little incentive to implement vehicle trip reduction programs if they are not granted reductions in minimum parking requirements. They would not be able to realize the potential cost savings from providing less parking, but would simply be faced with a large number of empty spaces. Some cities, such as South San Francisco (see box), have acknowledged this through ordinances that reduce parking requirements for projects that include vehicle trip reduction programs.

Pricing Strategies

Although parking is often provided at no charge to the user, it is never free. Each space in a parking structure can cost upwards of $2,500 per year in maintenance, operations, and the amortization of land and construction costs. Even on-street spaces incur maintenance costs and an opportunity cost in forgone land value. These costs end up hidden in rental fees and even in the costs of goods and services. Donald Shoup, Professor of Urban Planning at UCLA, has published extensively on parking policy in the United States. He believes that accurately pricing parking would solve many parking problems (Shoup, 2005).

The cost of parking is generally subsumed into lease fees or sale prices. However, providing anything for free or at highly subsidized rates encourages overuse and means that more parking spaces have to be provided. Charging users for parking is a market-based approach that passes the true cost of parking to users, and encourages use of other transportation modes. If the fee charged to users of parking facilities is sufficient to cover construction, operation, and maintenance costs, it may encourage some users to seek alternative transport modes. Even where there are few alternatives to driving, parking pricing can encourage employees to seek out carpooling partners. In addition to reducing the cost of parking provision, pricing strategies bring substantial environmental and congestion benefits, particularly since they tend to reduce peak-period vehicle trips the most.

Travel Demand Management Ordinance

South San Francisco, California

South San Francisco is one of the few cities in the U.S. to enact a citywide Transportation Demand Management (TDM) ordinance, which allows reduced parking requirements for projects meeting TDM requirements. The ordinance applies to all nonresidential developments that expect to generate 100 or more average daily trips, or to projects seeking a floor area ratio (FAR) bonus. Parking reductions are not fixed, but are subject to case-by-case review and depend on the number and extent of TDM elements.

For example, the brownfield, mixed-use Bay West Cove development, which is located close to transit and bus service, was able to reduce required parking by 10 percent by implementing the following TDM strategies:

- Free parking for carpools and vanpools.
- Late-night taxi service and feeder shuttle service.
- Transit subsidy of $25 per month for all tenant employees.
- Late-night taxi service and feeder shuttle service.
- Guaranteed ride home program.
- Provision of a transportation coordinator.
- On-site project amenities such as child care, showers and lockers, electric vehicle charging, bicycle storage facilities, and a transit information kiosk.
- Parking charges of at least $20 per month for employee parking spaces.

Developers can use the savings from reduced parking construction and the income from paid parking to offset or cover the costs of implementing such programs.

Source: City of South San Francisco, 2003.

However, free parking is an ingrained American tradition. An estimated 99 percent (Shoup, 2005) of parking in the United States is free. How can paying for parking ever be a good thing for drivers? Drivers are willing to pay for parking that is more convenient and readily available. For example, on-street spaces near shopping destinations are much more likely to be available to customers if priced and regulated to prioritize short stays -- if they are free, they will be used for all-day parking by employees or residents. For residents, separating the cost of parking from the cost of rent or a mortgage provides an economic benefit to those who choose to own fewer cars. In addition, the revenue generating from putting an accurate value on parking can be used to benefit an entire neighborhood.

For commuters, making the cost of parking part of the decision on how to get to work encourages transit use and other alternatives, reducing traffic congestion. Parking charges have been found to reduce employee vehicle trips, and thus daily parking demand, by between 7 percent and 30 percent or more, depending on factors such as the level of charges and the availability of alternatives to driving alone. One researcher has calculated that each 1 percent rise in parking fees is accompanied by a 0.3 percent decrease in demand (Pratt, 2000).

Cities and developers are using a variety of pricing strategies to better balance parking demand and supply. They include parking cash-out programs, pricing that prioritizes certain types of trips, residential parking plans, and parking benefit districts.

Cash-Out Programs

Cash-out programs allow employees to choose a transportation benefit, rather than simply accepting the traditional free parking space. Under such programs, employers offer employees the choice of:

- Free or subsidized parking,
- A transit or vanpool subsidy equal to the value of the parking (of which up to $100 per month is tax-free under current federal law), or
- A taxable payment approximately equal to the value of the parking, essentially cash to commuters who bicycle or walk to work.

Employees who opt for the non-parking subsidies are not eligible to receive free parking from the employer and are responsible for their parking charges on days when they drive to work. The cost savings for employers

associated with cash-out payments depend on the amount of the payments. If the full cash equivalent is provided, this demand reduction program does not reduce the total costs of providing parking. However, employees may accept cash payments lower than the full equivalent of the parking subsidy. If partial cash payments are used, employers face lower overall transportation subsidy costs, and employees still benefit. The programs help end the inequity of providing a free parking space benefit to drivers, while offering nothing to those who choose to arrive via transit, foot, or bicycle.

Cash-out programs are often easier to implement than direct charges, as they are generally more acceptable to employees, particularly when free parking had been the norm. However, their impact on travel behavior is usually lower, due to the administrative burden on employees, inertia in changing travel habits, and the fact that cash-out payments can be a taxable benefit whereas free parking is not.

Cash-out programs provide significant environmental, social, and economic benefits. For example, in response to California's mandatory cash-out requirement, eight firms reported an average 17 percent reduction in the total number of solo drivers (Shoup, 1997a). Thus, another benefit of cash-out programs is a reduction in traffic congestion and associated pollution.

Cash-Out Program

Santa Monica, California

In 1992, California instituted a mandatory cash-out program. The California Health and Safety Code Section 43834 reads, "'Parking cash-out program' means an employer-funded program under which an employer offers to provide a cash allowance to an employee equivalent to the parking subsidy that the employer would otherwise pay to provide the employee with a parking space."

The effects of the cash-out program on transportation use in Santa Monica have been significant. A study conducted by Donald Shoup of the UCLA found that for two Santa Monica employers, the share of solo commuters decreased by between 7 and 8 percent once the cash-out program was in place. This reduction in solo commuters is responsible for a decrease in annual commuting of 858 vehicle miles (Shoup, 1997a).

Prioritizing Trips

Parking pricing can be a tool to prioritize some types of trips over others, according to their purpose and duration. It allows managers to cater to certain users, such as short-term shoppers, while discouraging other users, such as commuters, who add to peak-hour congestion and occupy a parking space for an entire day. These pricing strategies allow the overall supply of parking to be minimized, while ensuring spaces are available for critical users. They can also alleviate pressure to provide more parking from retailers and businesses, who may be concerned that lack of parking discourages shoppers. For example:

- Low prices for short-term parking encourages shopping trips, and limiting the duration of parking can also support these high-turnover trips. For example, charging $0.25 per hour with a two-hour maximum will allow many people to use a single space over the course of a day. The same space priced at $2.50 for up to ten hours will likely serve a single commuter. The parking revenue might be the same, but the sales for businesses and sales tax for the city will likely be much higher with short-term parking.

- Parking charges that are levied by the hour or day, with no discounts for monthly parking, remove the incentive to drive every day to "get your money's worth" from the monthly parking pass.
- Parking charges at transit stations that only apply before a certain time (such as 9:00 am) encourage users to ride transit when it is less crowded, rather than contributing to crowding in the peak.
- Sophisticated new parking meters can charge visitors a different rate than residents or employees with parking permits, preserving parking for regular users while maximizing revenue from occasional users.

Residential Parking Pricing

Parking charges can also be introduced at residential developments, through separating or "unbundling" the cost of parking from rents or sale prices. Rather than being provided with a set number of spaces whether they need them or not, residents can choose how many spaces they wish to purchase or rent. An alternative to direct charges is to provide "rent rebates" or discounts to residents who own fewer vehicles and do not use their allocated parking spaces.

In many urban areas with limited off-street parking, curb parking is reserved for residents through residential parking permit programs. In most cases these programs give residents free or very inexpensive curb parking permits and prohibit anyone else from parking there. However, this can leave many spaces unused during the day when nearby businesses could use extra parking. A few communities, including Aspen Colorado and Tucson Arizona, are experimenting with allowing businesses to buy permits in these areas at very high rates, or are charging hourly parking fees (Shoup, 2005). The revenue generated can be used to benefit the neighborhood, in one version of a parking benefit district, as described below.

Parking Benefit Districts

The revenue from parking can be used to directly benefit the street or the neighborhood where the money is collected. Parking benefit districts receive the revenue from meters and residential permits within the district. Once administrative costs are covered, all money goes to transportation and neighborhood improvements such as undergrounding of utility wires (Shoup, 1995), regular street and sidewalk cleaning, installation of benches, nice lighting, or other amenities. Parking benefit districts can allow new development to use available on-street and other spaces, while addressing potential capacity problems through market pricing of curb and off-street parking. Earmarking revenue to directly benefit the neighborhood or commercial district helps to generate support for charges from local residents and businesses, who might otherwise resist paying for parking that used to be free. Often, local residents or businesses have a say in how the newly available revenue will be spent.

The most common use of Parking Benefit Districts has been in downtown business districts, usually using parking meter revenue. Cities such as San Diego and Pasadena, California, have implemented such districts. The concept also applies to residential areas. Most residential parking permit programs give residents free or very inexpensive curb parking permits and prohibit anyone else from parking there. However, this can leave many spaces unused during the day when nearby businesses could use extra parking, and neighborhoods could certainly use the revenue that could be generated by charging for street parking.. A few communities, including Aspen Colorado and Tucson Arizona, are experimenting with allowing businesses to buy permits in these areas at very high rates, or are charging hourly parking fees (Shoup, 2005). Furthermore, this concept can be refined based on the neighborhood. For example, a neighborhood adjacent to an institution such as a hospital or university might implement a two-tiered residential permit program. Residents could buy permits at one rate, while excess on-street capacity would be sold at market value to non-residents.

Case Studies

This section presents case studies that illustrate how specific metropolitan areas have benefited from innovative parking alternatives. Little data has been collected comparing the effectivness of various parking strategies, and much cost data is proprietary and not available for analysis. Therefore, these examples are presented to illustrate the ways that parking strategies are being used in real-word settings to help communities balance parking and other goals.

- Portland, Oregon: Parking policies include maximums, location- and use-specific requirements, shared parking entitlements, car-sharing, and vehicle trip reduction or Transportation Demand Management (TDM) measures. The Hilton Hotel and the Buckman Heights and Buckman Terrace apartments have used these policies to alter their parking mix..
- Arlington County, Virginia: Location- and use-specific standards and vehicle trip reduction strategies were used to reduce parking requirements in two developments, the Market Common and the 1801 North Lynn Street commercial development.
- NASA Research Park, Santa Clara County, California: A large mixed-use development illustrates vehicle trip reduction strategies
- The Shoppes of Wilton Manors, Wilton Manors, Florida: This case illustrates how shared parking arrangements can be used to reduce parking requirements for a mixed-use redevelopment in one of the fastest growing areas of the country.
- SAFECO Insurance Company Expansion, Redmond, Washington: SAFECO responded to the state's transportation demand management requirements with an effective vehicle trip reduction program.
- The D'Orsay Hotel, Long Beach, California: This case illustrates how a downtown parking management plan that allows shared parking and in lieu parking fees can reduce development costs and put scarce land to productive use.

These six case studies were chosen to highlight the range and depth of parking alternatives, including those created for a specific development basis and those written into code. The case studies include some description of outcomes, including parking costs and development decisions; support for compact, mixed-use, walkable communities; and other goals. As city and county jurisdictions, Portland and Arlington have innovative approaches to managing their transportation systems, including parking, and the case studies illustrate how these policies affect specific developments.. Arlington County is an example of code-based parking reduction strategies—it encourages reduced parking primarily through lowered minimum requirements. Portland, on the other hand, has a varied toolbox of strategies to offer developers to reduce parking. In other cases, specific developments took the initiative to go against development trends in reducing parking.to achieve broader goals, such as the NASA development in California. For the Wilton Manors (Florida) and D'Orsay Hotel (California) cases, the lowered cost associated with parking alternatives was a key element that allowed the projects to be built in a way that satisfied multiple goals of the community and developers. The parking alternatives can also provide directly documentable environmental benefits: SAFECO's use of transportation management measures and development design, limited air emissions associated with automobile commuting and protected water quality. Parking alternatives used for The Shoppes of Wilton Manors and D'Orsay Hotel developments facilitated these infill projects, thus preventing additional sprawl and the associated air and water quality impacts.

Innovative Parking Policies: Portland, Oregon

Portland, Oregon, has introduced several innovative planning policies (listed in the box on this page) to balance transportation needs with environmental protection, community design, affordable housing, and other goals. The two developments profiled below are just a sample of the numerous projects that have taken advantage of the city's parking reduction policies to achieve economic, environmental, and social benefits. Others, in brief, include:

■ Stadium Station Apartments: 115 affordable apartments, with parking at 0.6 spaces per unit. Of the 40 units already leased, only one-third of households own automobiles. Despite already low parking ratios, 50 percent of the parking remains unused at full occupancy.

■ Orenco Station and La Salle Apartments: Both have parking reductions to 1.8 spaces per unit and provide transit pass allowances to residents. This has achieved a large increase in

Innovative Parking Policies
Portland, Oregon

Portland has adopted a range of parking policies to promote infill development and balance driving and alternatives to the private car, including:

- No minimum parking requirements in the central city;
- Parking maximums in most neighborhoods, including downtown;
- Transferable parking rights in areas with parking maximums;
- Reductions from typical minimum requirements for car-sharing vehicles;
- Reductions from typical minimum requirements for vehicle trip reduction strategies, such as transit access and bicycle parking;
- Context-specific standards; and
- Provisions for shared parking.

transit ridership among occupants.

- Collins Circle, Center Commons, and Russellville Commons Apartments: each is able to serve residents with a combination of transit access, walkability, and fewer than one parking space per unit

Hilton Hotel

The Hilton Executive Tower Hotel and garage, developed by Melvin Mark Companies, is in the heart of the Portland downtown business district, within the Free Transit Zone. Constructed on a block that was the former home to the Greyhound bus terminal, the 20-story, 440,000-square-foot project consists of 312 hotel rooms, conference space, 20,000 square feet of ground-floor retail, and 680 parking spaces. The Hilton Hotel is the owner of the hotel portion of the project, and a Melvin Mark partnership owns the parking structure. Under the Portland zoning code, the maximum allowed parking for the development would have been 380 spaces—312 hotel spaces, plus 68 growth spaces for the retail.

The developers recognized that unmet demand for parking existed in Portland, but not primarily from hotel visitors. They sought to make the new parking available to other users, which would make it more efficiently used (and profitable) than if it were restricted to hotel use. They were able to accommodate needs of the new development and surrounding uses by building 680 spaces — more parking than downtown Portland parking maximums allow. This case study illustrates not only the benefits of shared parking, but that parking maximums combined with transferable parking entitlements can increase the value of real estate and development.

Under the Portland zoning code, the maximum allowed parking for the development would have been 380 spaces—312 hotel spaces, plus 68 growth spaces for the retail. These maximums are lower than both the parking generation rates published by the Institute of Transportation Engineers, and the *minimums* adopted by most cities. The maximums for new office and retail development downtown are one space per 1,000 square feet; for hotels, the maximum is one space per room.

The city views the parking maximum as an “entitlement.” New developments can either build the parking “entitlement” (the maximum parking allowed) or can transfer those spaces to another development, as long as the transfer contract is signed before the foundation is laid. Buildings that choose not to build the parking they are entitled to, or historic buildings constructed before parking became an issue, are granted an entitlement of 0.7 spaces per 1,000 square feet—70 percent of the parking entitled to new construction—which they can transfer to other developments at any time. Transferred rights are generally not sold, but are granted under certain rules that allow the project delivering the parking rights to reserve use of some of the spaces -- but at market rates paid to the development that built the parking.

In addition to parking limits, the city also has created three different types of parking spaces applicable to the Hilton Hotel development:

- **Hotel spaces**: By code, these spaces may only be sold to hotel users (guests or visitors) between the hours of 7:00 a.m. and 6:00 p.m., weekdays. If the hotel is in a slow season, or if not all hotel visitors want parking, the remaining parking spaces go unused—a potential financial liability.
- **Growth spaces**: These are the spaces entitled to new development. They have no constraints and can be sold however the developer sees fit.
- **Preservation spaces**: These are spaces generally entitled to older and historic buildings that were constructed without parking. They are more restrictive than growth spaces; if they are not used by building occupants, they can only be sold to other cash users on a daily or hourly basis.

The Hilton project combined these two policies -- the transferable rights and the categorization of parking spaces -- to build enough spaces to serve both the hotel and surrounding developments. The spaces built include:

Courtesy of Melvin Mark Companies

- 100 hotel spaces allowed under the zoning code, but restricted to use by hotel visitors (only 30 percent of their entitlement in this category).
- 68 growth spaces allowed for the retail space under the zoning code (100 percent of their entitlement).
- 512 spaces by transferring the parking entitlement from nearby buildings and new projects:
- 200 growth spaces transferred from a concurrent project, the 250,000 -square-foot Pioneer Place mall. The project wanted the parking to attract customers, but did not want to assume development costs or lose retail density on the site to parking.
- 312 preservation spaces transferred from seven buildings in the area. Most of these were office buildings built at a time when parking was not included.

Transferable parking rights made the Hilton/Melvin Mark development financially beneficial to all parties involved. The Hilton project would not have been feasible had its developers not been able to get the additional parking spaces and the flexibility to manage parking. As a major revenue component, the transfer of parking entitlements allowed the developers to secure funding from lenders. Prior to development, they were able to sell 500 monthly parking passes to managers of the buildings from which they had obtained preservation space rights. Like pre-leasing an office building, this committed revenue helped in obtaining financing. The additional parking and more flexible preservation and growth parking spaces also reduced risk and seasonal fluctuations that the code's "hotel use" parking constraints present. The garage operates with day-to-day averages of 85 to 90 percent occupancy from being able to sell to many different users—a major source of revenue for the project.

Transferable parking entitlements retains the advantages of maximum parking requirements, such as reduced vehicle trips and reduced land area devoted to parking, while creating flexibility and a potential for profit that attracts major developments to the area. In this way, transferable parking entitlements help to reinforce the economic health of the central city, and important goal in the Portland region. Downtown development ensures that the city of Portland retains its property tax base, promotes an active and pedestrian-friendly downtown with multiple amenities, and produces more foot traffic for surrounding businesses. Pioneer Place mall, for example, attracts more customers by having available parking at an adjacent site, without adding the risk of developing parking or losing retail space on their property.

Portland Hilton Executive Tower

Profile:

- Hotel, conference center, retail, parking garage
- 312 hotel rooms
- 20,000 square feet retail
- 680 shared parking spaces – 45% more than typically allowed under parking maximums

Strategies:

- Transferable parking entitlements
- Parking maximums
- Shared parking

Benefits:

- Increased parking revenue helped attract major downtown development
- New parking benefit provided for older downtown buildings without their own garages
- Shared use reduced impact of extra, empty parking spaces

The preservation buildings that transferred their spaces to Melvin Mark Companies also reap significant financial benefit. Typically older, commercial buildings are at a market disadvantage for leasing space because they cannot provide or commit parking for their tenants in office leases. With parking built at the Hilton/Melvin Mark garage and preferential rights to lease to their tenants, the older buildings compete on a more level playing field with newer buildings for prospective tenants.

Buckman Heights and Buckman Terrace

Located adjacent to Portland's central city Lloyd District and along the edge of a light-industrial area, the site of the Buckman Heights mixed-use development and the Buckman Terrace Apartments was used for decades as a car dealership. Despite a heated real estate market, the 3.7-acre site had been on sale for well over a year, unattractive to most developers. Prendergast & Associates saw an opportunity to build housing on the site, given its prime location—the project is located nine blocks from light rail, within five blocks of four high-frequency bus lines, and surrounded by a growing network of bike lanes and routes. It is also within easy walking distance of jobs in the Lloyd District, the Central Eastside, and downtown. In part because of Portland's parking policies, Prendergast was able to purchase the site in 1997,

Courtesy of Pendergast & Associates, Inc.

sell the dealership building to a retail user, and convert the remaining 2.5 acres of vacant parking lots into sites for 274 units of housing—an 8-unit townhouse project, a 144-unit mixed-income apartment building, and a 122-unit apartment building with a small retail space. Creative parking strategies helped to keep development costs low.

The city of Portland has very low minimum parking requirements in the area. Zoned for general employment, with housing allowed but not actively encouraged, the minimum parking requirements were just 0.5 spaces per unit—already a significant reduction from the typical urban standards of between one and two spaces per apartment. This neighborhood is close to transit and jobs, providing consumers with a choice of different housing types and mobility options.

Both developments have extremely low parking ratios. Buckman Heights has 58 on-site parking spaces for a ratio of 0.4 spaces per unit. Buckman Terrace has 70 spaces at a ratio of 0.57 spaces per unit, with only on-street parking for the retail. These spaces are a mix of carport, surface, and at-grade structure spaces.

The developmenter was able to both reduce the parking required and keep parking demand lower than supply through the following strategies:

- **Bicycle Facilities:** Buckman Heights Apartments eliminated 14 required on-site parking spaces by providing 56 secure, covered bicycle parking spaces in addition to the 36 spaces required by code. Portland zoning provision allows four covered, secure bike parking spaces to be substituted for one automobile parking space, up to a maximum of 25 percent of the required parking. The developer also provided lockers, floor pumps, and a workstand in the bike rooms. The bicycle parking has been so well used that the developer added even more bike parking to Buckman Terrace.
- **On-street parking:** The Buckman Heights development included restriping a wide street between the two apartment buildings to accommodate angled parking, increasing the supply of on-street spaces as well as creating a more pedestrian-friendly feel through the addition of generous sidewalks, landscaping, and street lamps. Although this did not directly replace the requirement for off-street spaces in this case, it provided a buffer and allowed the development to build as little parking as possible.
- **Shared off-site parking:** The development made use of on-street parking in the adjacent area where a sewing/assembly plant and a high school were located. The adjacent uses had huge on-street

Buckman Heights Apartments and Buckman Terrace

Profile:
- Mixed market-rate and affordable housing with modest retail
- 144 units and 122 units, respectively
- Parking ratios of 0.4 and 0.57 spaces per unit, respectively

Strategies:
- Parking maximums
- Use of on-street parking
- Shared off-site parking
- Car-sharing and bicycle parking available
- Parking charges separated from rents

Benefits:
- Lowered parking ratios increase affordability: 40% of Buckman Heights units are affordable
- Elminating excess parking saved Buckman Terrace developers at least $875,000
- Eliminating excess parking made room for more affordable units
- Residents benefit from affordable transportation options: bicycle facilities are well used

parking demand during the day (when residents are typically at work) but were empty on evenings and weekends (when residents are typically home and parking their cars). This unique setting allowed the developer and the lenders to feel comfortable with the sharply reduced on-site parking ratios.

- **Unbundled Parking Costs:** Paying for parking separately from rent helps keep residents aware of parking costs and allows them to make informed, economic choices about vehicle ownership and other transportation options. Parking at Buckman Heights costs between $15 and $30 per month, depending on surface or covered spaces. Buckman Terrace parking (structured) costs $50 per month.
- **Car Sharing:** FlexCar (originally CarSharing Portland) now has two vehicles at the complex. Since car-sharing was not available at the time of construction, it did not reduce the amount of parking that had to be built, but it now reduces the need for residents to own cars and, consequently, the demand for parking.

Keeping development costs low was particularly important because the project was not eligible for property tax abatements that are given to low-income and central city market-rate housing, because it lies just outside the central city boundary. By cutting costs, partially from parking, the developers were able to secure the funding needed for development.

Courtesy of Pendergast & Associates, Inc.

Considering per space construction costs in Portland of $5,000 to $7,000 for surface parking, upwards of $15,000 for surface structures, and $25,000 to $30,000 for below-grade structures, parking reductions in the Buckman developments significantly reduced development costs. Buckman Terrace was constructed with no surplus land, so additional parking would have been forced to go underground. By forgoing the construction of 50 additional spaces, the developers were able to reduce the cost of the apartments with the savings of between $875,000 and $1,125,000. For Buckman Heights Apartments, the developers were able to add additional apartments to the project using the money saved from parking, especially helpful for revenue given rent restrictions on the affordable units.

The attention to a walkable environment has given the residents more transportation choices and improved their quality of life, while also making the project marketable. Both developments have been at or near full occupancy (95 to 100 percent leased) since the openings in 1999 and 2000, even outperforming the soft Portland housing market in recent months. The developments have provided more than 80 new affordable homes. In addition, charging for parking separately from rent benefits households who do not have cars—particularly low-income families. Infill housing also increases the city's tax base.

Context-Specific Requirements and TDM: Arlington County, Virginia

Arlington County is an urban area of about 26 square miles directly across the Potomac River from Washington, DC. Arlington County has adopted countywide development standards and guidelines, including lower parking ratios, to support future growth of high-density commercial and residential development around Metrorail stations in their two corridors—the Rosslyn-Ballston Corridor and the Jefferson Davis Corridor. Two specific projects are profiled here—a high-density residential development and a commercial development. Both have used the county's context-specific parking requirements and travel demand management program to better match parking supply with demand, making resources available for other community benefits.

Context-Specific Requirements
Arlington, Virginia

Commercial Uses:

- Commercial Office Zoning area outside of station areas: one space per 530 square feet.
- Commercial Redevelopment Zone (along Metro Corridor): one space per 580 square feet.
- Rosslyn-Ballston Metro Corridor Development and developments within one-quarter mile of a Metro station: one space per 1,000 square feet.

Retail Uses:

- For retail and service-commercial uses within 1,500 feet of a Metro station, no parking is required for the first 5,000 square feet of gross floor area.
- Any square footage above that has the same parking requirements as commercial in the area (either 1:580 square feet or 1:1,000 square feet, depending on its location in the corridor).

Residential Uses:

- High-density residential: 1.08 spaces per unit (1:1 + visitor).
- Townhouses: 2.2 per unit (2:1 + visitor).
- Single family homes: one space per house. This ratio assumes space in a driveway or on the street.

Arlington County dictates minimum parking requirements based primarily on distance from Metro stations. Parking requirements for commercial development are particularly transit-sensitive, with the lowest ratios for properties closest to Metro stations. According to Richard Best from the county Public Works Planning Division, if a development is within one-quarter mile of a Metro station, the county is open to allowing development with no new on-site parking, although this is not specifically written in the code.

Every project that goes through the site plan process for development along Metro corridors is required to have a transportation plan, which varies depending on density and use. Further reductions in minimum parking requirements, beyond the location- and use-specific standards, are granted for projects that include robust transportation choices, such as free or discounted transit passes for employees, other transit subsidies, ridesharing, and information on transit.

While not written into code, Arlington also enforces urban design criteria in parking construction. All parking is encouraged to be below ground, or if at surface level, it must be in a structure that is wrapped with occupiable ground floor space, in order to reduce the impact of the parking on the walkability of the street. There are no codes dictating such design, but a site-plan review process strongly encourages it.

The Market Common

The Market Common in Clarendon is a mixed-use development with retail and restaurant space, 300 market-rate apartment units on upper floors, and adjacent office space. Located three blocks from two Metro stations along the Rosslyn-Ballston corridor, and in close proximity to dense employment and retail, the area has a variety of uses and urban form that supports walking, transit, and biking as well as driving and parking. Realizing that patrons of retail establishments would be using the parking during the day while residents would mainly need parking at night, developers of the Market Common devised a shared parking strategy.

Courtesy of McCaffery Interests

Courtesy of McCaffery Interests

Under typical suburban parking requirements, the development would have required over 2,000 parking spaces.Under the Arlington County Code, the project would have required 1,504 spaces for the retail, housing, and office space. But by using a shared parking strategy, the development was able to reduce the requirement by 25 percent—to 1,160 spaces. The Market Common is the first recent development approved in the county with no assigned spaces for residential units—all spaces are equally available for all uses.

Parking demand is mitigated through several strategies:

- Parking costs are unbundled from rent for residents: $25 per month for the first car, $75 to $100 per month for the second;
- Daily parking is variable for other users, with rates of $1 to $4 per hour, with higher rates for longer stays;
- Bicycle parking reduces demand, as does proximity to transit.

Perhaps the parking could have been reduced even more and still met demand. Studies of parking use at Market Common indicate that up to 20 percent of available parking remains unused at peak times. The developer and county agreed to count that surplus parking toward requirements at future phases of this development.

The Market Common

Profile:

- 225,000 square feet of retail and restaurant use
- 300 market-rate apartment units
- Parking: 25 percent reduction from county code

Strategies:

- Shared parking
- Parking costs separated from rents
- Transit and bicycle facilities

Benefits:

- Fewer required spaced reduced development costs by an estimated $16 million
- Parking paid for only by those who use it

1801 North Lynn Street

The 1801 North Lynn Street development is a new commercial building in the Rosslyn Metrorail station area, zoned for parking requirements of one space per 1,000 square feet, dependent upon the choices available to travelers. The zoning in this area permits increases in density and height when the County Board finds that the development offers important community benefits. The 1801 North Lynn Street development has 347,295 square feet of office space, 6,065 square feet of retail, and 386 parking spaces. At typical suburban parking ratios, that amount of development would have been accompanied by roughly three times as many parking spaces. Transportation Demand Management strategies allowed parking to be reduced to one space per 1,000 square feet ratio. The transportation program included the following elements:

> **1801 North Lynn Street**
>
> Profile:
> - Office building with street-level retail
> - 348,000 square feet of office space
> - 6,000 square feet of retail space
> - 386 parking spaces, one-third of typical requirements
>
> Strategies:
> - Extensive TDM program including fare subsidies
> - Bicycle, pedestrian, and transit facilities
>
> Benefits:
> - Employees have a range of commuting choices
> - Eliminating unnecessary parking helped make project financially feasible
> - Increased tax base from new commercial activity

- Full-time, on-site Employee Transportation Coordinator to manage the program;
- Financial contribution to the Rosslyn Commuter Store;
- Transit fare subsidies for employees;
- Implementation of several ridesharing and parking strategies, including promoting ridesharing, helping commuters find rides, and subsidizing parking for carpools and off-peak commuting; and
- Bike facilities and showers to encourage bicycle commuting.

For workers in this building, the discounted Metro fare, along with walking and biking access to many residential neighborhoods, provides real choices in how to get to work. For shoppers at its retail establishments, newly available on-street parking in front of the stores provides a better option than existed before. The county gets an increased tax base and the vitality of mixed-use development and street-level retail in an area that in the past has not enjoyed off-peak activity.

Financial benefits to the developers of the two Arlington County projects are obvious -- reduced parking requirements sharply reduce construction costs, which in Arlington can mean upwards of $15,000 per space for structured parking, and up to $25,000 or more for below-grade spaces. Building less parking is a major part of making the projects financially feasible, in terms of balancing land costs, construction costs, revenue, and lending. The Market Commons project, for example, saved $16 million from the 400 forgone parking spaces, without which it would not have been a feasible project.

Arlington has succeeded in promoting high-density, mixed-use developments with reduced parking in its Metrorail corridors. This kind of design promotes walk and bike trips as people can go from home to work and shopping in very short distances. Urban design in both projects pays close attention to pedestrian comfort, by providing usable public space, circulation paths, attractive landscaping, and engaging street-level architecture.

Transportation Management for Mixed-Use Development: Santa Clara, California NASA Research Park

The NASAAmes Research Center (ARC) is a 1,500-acre site of federally owned land that lies between the southwestern edge of the San Francisco Bay and Silicon Valley, in Santa Clara County, California. Part of the site includes Moffet field, a decommissioned military site. Years of planning and community input led to an award-winning plan for a mixed-use development including an emphasis on research and technology firms; Internet-search giant Google recently announced it would build a major campus at the site. Design and construction will continue through at least 2014.

The majority of redevelopment on NASA's land will occur in the NASA Research Park (NRP), a 213-acre parcel on the southwest part of the site. Plans for development include the restoration of existing historical buildings, as well as adding nearly two million square feet of educational, office, research and development, museum, conference center, housing, and retail space. Also being developed as part of the project is 28 acres of a 95-acre parcel on the north side of the site called "The Bay View." This area is slated for predominantly housing uses, in addition to supporting retail, childcare, and other services. The remainder of Bay View will remain as open space and natural habitat.

Because the NASA land is federally owned, it is exempt from city or county codes that dictate parking requirements, as well as other development restrictions. Despite the lack of restrictions, the NRP project sought from the beginning to reduce the impact of traffic on surrounding streets and neighborhoods—with the goal of keeping driving at least 32 percent below the typical rates by Santa Clara County residents.

Had the site been developed using typical minimum parking ratios, it would have needed 7,542 parking spaces. Instead, the TDM plan calls for 5,200 spaces, with parking ratios determined by the actual number of people expected to be on-site.

A TDM plan was developed for the NRP and Bay View, using a range of trip reduction strategies to ensure that parking demand can be accommodated in fewer spaces The TDM plan will be binding on partners and other tenants at the NRP and Bay View developments, pursuant to the provisions of the environmental permits.

Some of the many innovative TDM strategies to achieve the plan's goals include:

- Supportive site design, including housing, retail, and office space in close proximity; bicycle paths and bike parking; a network of sidewalks and paths;
- Oh-site employees and students get priority for purchasing on-site homes
- Site-wide shuttle bus program and bus pass;
- Partners, lessees, & tenants are required to pass on the cost of parking or offer parking cash-out;
- Parking fees structured so the less you park, the less you pay: o discount for monthly parking; hourly spaces; low rates for carpoolers
- 75 percent of all spaces shared between land uses.

NASA Research Park and Bay View

Profile:
- Partially redeveloped 1500-acre former military base with significant open space
- 1,120 town home apartments for 3,300 residents
- 810 dormitory-style housing units for 1,560 students
- Renovation of 600,000 square feet of historic buildings
- Addition of more than three million square feet of new housing, office, and retail space
- 5,200 parking spaces, 32 percent less than typical development codes require

Strategies:
- Mix uses to reduce vehicle trips
- Bicycle and pedestrian facilities and shuttle bus
- Parking pricing policies
- Specific TDM goals for commuting trips, including 32 percent fewer vehicle trips than area average

Benefits:
- Reduced traffic impact on surrounding communities
- Less pavement reduces impact on natural habitat
- Convenient housing and commuting options for residents and employees
- Reducing unnecessary parking saves $3 million annually

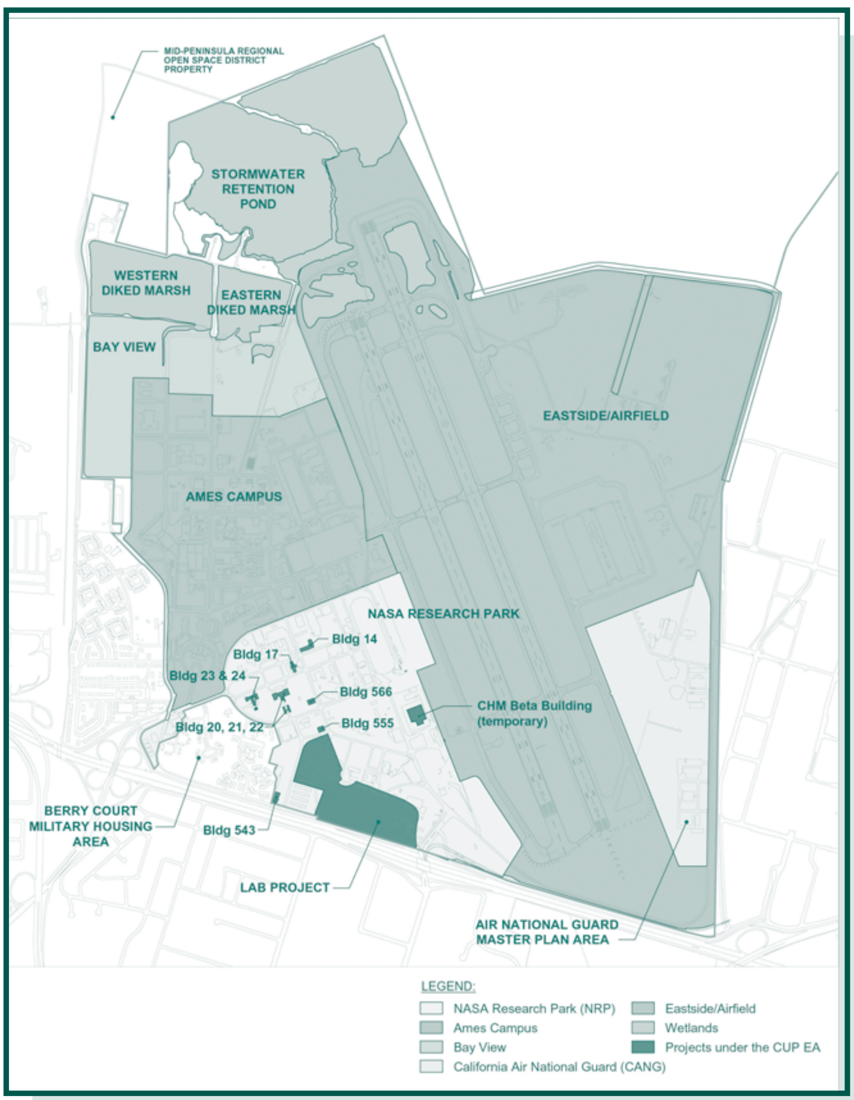
The TDM plan allows for adjusting the price of parking to balance demand with supply. This flexibility provides revenue for TDM programming while ensuring efficient use of the parking. The TDM program means significant cost savings for developers, while reducing the environmental impact and improving the pedestrian environment of the future campus.

Without the TDM program, the development would have needed an additional 2,342 parking spaces, at a cost of about $3 million annually. Parking fees cover all costs of providing parking and the TDM program, a benefit to both the developer and surrounding communities: The TDM program requires that those who park pay for the parking supply. Travelers who want to drive can park, while travelers who choose not to drive do not have to pay for it.

The land itself is a brownfield—formerly contaminated by its military use—as well as an environmentally sensitive habitat—home to the burrowing owl, a California species of special concern. The development focuses on remediation, preservation, and environmental sustainability. The development plan goes a step further to ensure conservation for a sustainable future—it incorporates energy efficiency, water conservation, transportation demand management, and seismic safety. This is a striking change from typical development patterns in the area.

The NRP TDM plan will reduce impervious pavement, an element of development that can damage nearby ecosystems because of reduced habitat, limited rainwater re-absorption, and increased polluted stormwater runoff. Reduced parking in the NRP saves land, which contributes to the project's 81 acres of preserved land for the endangered burrowing owl.

By combining uses on the property and offering on-site employees and students priority for purchasing homes, the development will not only reduce the need for people to commute from out of the region, but will sharply reduce internal vehicle trips. The development will be home to nearly 5,000 people, at least half of whom will work or study on the campus. These employees will be able to find services on site, instead of having to run errands off site on their lunch breaks. NASA has committed to offering a minimum of 10 percent of the homes on site at prices affordable to its employees. The reduced parking is not an end in itself. It underscores the emphasis on better urban design and improved walkability, improving the quality of life of residents,



employees, students, and visitors.

Reduced Parking Requirements: Wilton Manors, Florida The Shoppes of Wilton Manors

In the city of Wilton Manors, in Broward County, parking reductions were partly responsible for enabling a financially deteriorating neighborhood shopping center to be redeveloped into a successful mixed-use development, featuring restaurants, art galleries, and other entertainment uses, as well as professional offices. At its peak in the 1960s, the shopping center housed a Grand Union supermarket, a bank, a fast food restaurant, and many other stores. In the 1990s, the shopping center lost several businesses, reducing the tenant occupancy rate to 30 percent.

The Shoppes of Wilton Manors

Profile:
- Redevelopment of neighborhood shopping center
- Converted to an entertainment destination
- Eliminated construction of 390 unnecessary parking spaces

Strategies:
- Zoning overlay district recognizes lower demand for parking
- Off-site shared parking facilities

Benefits:
- Buildings preserved for rental, rather than demolished for parking
- Saved $1.9 million in construction costs
- Increased property values and city revenues
- Helped inspire nearby redevelopment

Southeast Florida, comprising Palm Beach, Broward, and Dade Counties, is one of the fastest growing regions of the United States. Projections for 2015 suggest that the population will reach 6.2 million people, an increase of over 50 percent from 1990. With the growing population and increasing development, fragile ecosystems are being lost and water supplies threatened. Communities and this region are seeking to reverse these trends by developing compact, mixed-use, walkable places. Reducing parking requirements is one element of southeast Florida's move toward smart growth and development.

To accommodate redevelopment of the shopping center and revitalize the area, the city teamed with a private development company, Redevco, creating a public/private partnership to transform the property. Because a host of "big box" retail stores had recently located in outlying areas, this property could not support additional retail stores. Instead, the city and Redevco identified an untapped market niche—entertainment, cultural attractions, and restaurants. To enable these uses, the city created a new zoning overlay district that not only changed zoning requirements to allow arts and entertainment uses, but also exempted the developer from standard parking requirements by allowing shared parking in planned off-site public parking structures. The new zoning district also allowed outside cafes and seating to make the restaurants more inviting and attractive.

Under the city's generic parking requirements, art and entertainment uses would have required 390 new parking spaces, in addition to the existing spaces at the site required for existing retail. Construction of the additional

390 parking spaces would have cost approximately $1.9 million and would have also necessitated demolition of existing buildings, further increasing redevelopment costs and eliminating rental income from the lost buildings. Reducing the parking requirements and allowing shared parking reduced the development costs enough to make the redevelopment financially feasible.

The Shoppes of Wilton Manors now boasts full occupancy and rental rates of $32 per square foot (up from $8 per square foot). These two complementary factors—increased occupancy and increased rental rates—account for an increase in total annual rental income of $26 million, or 12 times its former rental income.

In addition to the financial success of the project, the revitalization of the Shoppes of Wilton Manors has provided other benefits to the community. The project has stimulated adjacent economic development. An office building next door that was vacant for 18 months now houses a law firm with 100 employees, many of whom frequent the restaurants and entertainment facilities at the Shoppes of Wilton Manors. Property values in the surrounding area are also improving; rental rates have almost doubled, from $6 to between $11 and $14 per square foot of leased space. The increased property value of the Shoppes of Wilton Manors—increasing by more than 10 times the initial value, from $226,000 to over $3.3 million—will add an estimated $80,000 in property tax revenues to the city. In addition, the other private investments along Wilton Drive have increased city-wide property tax revenues by 10 percent. Storefront and landscaping improvements make the area more attractive. Criminal activity has dropped due to the increased activity and vibrancy of the area. The walkable nature of the town center is enhanced as a result of improved site access. All of these benefits contribute to an improved quality of life for local residents and business people.

Some of the key elements in Wilton Manors' success include:

- The developer's and the city's willingness and commitment to work together;
- The city's flexibility in reducing parking requirements to support different redevelopment uses;
- Substantial cost savings resulting from parking reductions, making the redevelopment financially feasible; and
- Contributing to significant secondary benefits, including increasing the tax base and design improvements, by catalyzing surrounding development.

According to Redevco executive vice president, Debra Sinkle, the project succeeded because of the public/private partnership between the city and Redevco. The city's flexibility on zoning requirements and its commitment to the project created the confidence necessary for private investment.

TDM Program: Redmond, Washington SAFECO Insurance Company Expansion

The state of Washington's Commute Trip Reduction (CTR) law was passed in 1991 to improve air quality and mitigate traffic congestion. This transportation demand management measure targets the state's largest counties (those with populations greater than 150,000 people), requiring employers with more than 100 employees to implement programs to reduce single occupancy vehicle (SOV) trips to and from work. Through the state's CTR, employers monitor commuter travel patterns by administering employee surveys, which are written and processed by the state. The CTR established a goal of a 35- percent reduction in trips by 2005 compared to 1993 levels.

King County Metro
King County, Washington

- Washington's most populous county, with almost 2 million residents
- Metro transit serves 75 million riders per year, and 5,000 vanpool commuters each day
- Provides TDM support services to employeers

The headquarters of SAFECO Insurance Company of America is in Redmond, a suburb of Seattle in King County, one of the nine Washington counties affected by the CTR. SAFECO has responded to the CTR with an award-winning Transportation Management Plan (TMP) that includes employee transit passes, reserved parking for high occupancy vehicles (HOV), ride matching, vanpooling, and guaranteed rides home for employees at all its offices in the Seattle region.. By providing these services, SAFECO was allowed to build less parking for a recent expansion project below the city of Redmond's maximum levels.

SAFECO has undertaken a large-scale construction project to accommodate anticipated growth at its corporate headquarters in Redmond, adding three buildings (385,000 square feet of office space) and three parking structures (843 parking spaces) for the new office space. To preserve the attractive, park-like setting of the 48-acre campus and to maintain a pedestrian-friendly environment, SAFECO chose to construct all three parking structures underground. These subterranean spaces, while expensive to construct at $18,000 per space, preserve green space and make it easier to walk around the business park campus. The city of Redmond has maximum parking limits that would allow SAFECO to construct 1,155 spaces. Instead, SAFECO built 843 spaces, resulting in a parking ratio of 2.2 spaces per 1,000 square feet for the new office space. This amounts to a savings, relative to the maximum limits, of 312 parking spaces. Reducing the number of spaces allowed SAFECO to mitigate the higher cost of constructing underground parking, in addition to helping meet design goals.

While these parking reductions were not implemented as cost-cutting measures, the gross cost savings associated with the parking reductions (relative to the maximum limits) amount to $5.6 million in parking construction costs, or about $491,000 annually.[1]

SAFECO's exemplary TMP reduced parking demand and allowed the company to build fewer parking spaces. SAFECO targets a portion of the savings to the TMP, approximately $261,000 per year including $75,400 for transit subsidies. Combining the full cost of transportation demand management at the Redmond campus and the savings from parking reductions, SAFECO annually saves $230,000 from parking reductions. Given that SAFECO would have incurred some of the costs of transportation demand management at its Redmond campus regardless of the parking reductions, the net savings actually exceed $230,000. SAFECO's decision to increase the density of its existing property, rather than move to another (likely ex-urban) location, also avoided the cost of procuring additional land.

Under its TMP, SAFECO agrees to maintain the rate of employees driving to work alone at or below 60 percent. Since 1997, SAFECO has kept these trips to between 57 and 59 percent of total commute trips. By comparison, 81 percent of east King County commuters drive alone, and 13 percent carpool (Washington State Department of Transportation 1999). Rather than drive alone, 15 percent of SAFECO employees carpool; 12 percent use vanpool services; 8 percent use public transit; and the remaining 7 percent bicycle, walk, or telecommute.

The company also maintains information on commuter vehicle miles traveled (VMT). On average, SAFECO employees travel between 6.5 and 7 miles one way. Thus, by maintaining an average 58 percent SOV rate for its 1,700 employees, SAFECO averts as many as 4,635 VMT each day, or about 1.2 million miles each year. These VMT figures assume two people per carpool and four people per vanpool. Thus, if the carpools or vanpools transport a greater number of passengers, this reduction in VMT would be greater.

- ***Air Quality Benefits:*** The environmental benefits associated with this reduction in automobile commute miles are significant. Avoiding almost 1.2 million miles of automobile travel also avoids approximately 27.56 tons of carbon monoxide, 3.85 tons of nitrogen oxides, and 2.20 tons of hydrocarbons each year.[2]
- ***Water Quality Benefits:*** Another significant, yet less quantifiable, environmental benefit of reduced parking is the preservation of pervious surfaces to absorb rainfall and prevent polluted runoff. Increasing the amount of impervious areas through paving can alter

[1] This annual amount is only associated with construction costs and assumes constant payments, an interest rate of 7.25 percent, and a 25-year payment period per discussion with SAFECO transportation manager.

[2] Calculated using average emissions factors from EPA's Office of Mobile Sources' *Compilation of Air Pollution Emissions Factors, Volume II: Mobile Sources: (AP-42)*, which provides the following emissions factors: 21.05 grams of carbon monoxide emitted per VMT, 2.97 grams of nitrogen oxides emitted per VMT, and 1.71 grams of hydrocarbons emitted per VMT.

the area's hydrologic system and cause runoff mixed with oil and other contaminants to pollute receiving streams, rivers, lakes, and estuaries. With approximately 40 inches of precipitation each year and many fishable streams, the King County ecosystem is especially susceptible to polluted runoff. An additional 312 parking spaces in above-ground lots would mean another 100,000 square feet of impervious surfaces.

Several key factors contributed to the success of SAFECO's program.

SAFECO Insurance Company

Profile:

- Expanded office park by 385,000 square feet
- 843 underground parking spaces, 27 percent less than typical requirement

Strategy:

- TDM plan including vanpools, transit passes, guaranteed rides home

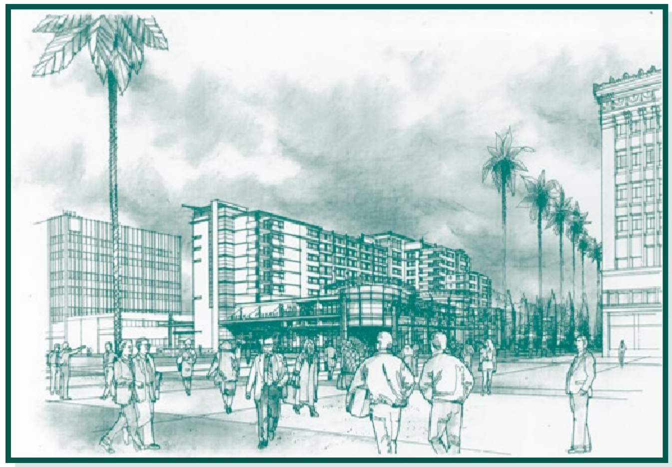
Benefits:

- Eliminating unnecessary parking saves $230,000 annually
- Employees avoid commuting costs and receive transit benefits
- Employees drive about 1.2 million miles less per year
- Less driving avoids about 33 tons of pollutants per year
- Reduced pavement for parking leads to less storm water runoff

- The city of Redmond was flexible and cooperative in allowing SAFECO to increase density on the existing property.
- SAFECO has an environmentally responsible corporate ethic of reducing parking below the maximum limits and staying in Redmond rather than relocating.
- Frequent and reliable public transit through King County Metro enables SAFECO employees to use alternative modes of transportation even when commuting from other towns in the county.
- SAFECO did not require outside financing. SAFECO's transportation management director believes that, had the project required outside funding, lenders might have resisted making loans unless more parking was provided in the development plan.

Shared Parking and In-Lieu Fees: Long Beach, California Embassy Suites at the D'Orsay Promenade

The city of Long Beach, California, recognizes that creating high-quality downtown development requires balancing the costs and supply of parking with other community goals, including economic development and walkability. In its Downtown Parking Management Plan, the city's redevelopment agency promotes small- and large-scale urban development by allowing for shared parking and in-lieu parking fees. The types of development projects eligible for these parking alternatives include non-residential new construction on lots less than 22,500 square feet, additions or rehabilitation to existing build-



ings, and renovation of historic landmark buildings.

The four-star Embassy Suites at the D'Orsey Promenade, which was proposed to the city in 1998, provides an example of how cities can use parking reductions to facilitate redevelopment. The proposed D'Orsay Hotel included a 162-room boutique hotel with 35,000 square feet of retail space. The property, on a three-block pedestrian walkway in downtown Long Beach was previously a surface parking lot.

Other development proposals for this property had been made to the city, but fell through in part due to the financial burden imposed by the city's minimum parking requirements. They would have required the developer to construct one parking space per hotel room and four spaces per 1,000 square feet of gross floor area (GFA) of retail space, totaling 302 spaces. With construction costs of $16,000 per parking space, the parking costs would have totaled $4.83 million, making the project fiinancially infeasible.

The developer worked with the city, which conducted a traffic study to assess parking demand at other Long Beach downtown hotels. The city's planning department determined that this mixed-use hotel and retail development did not require the minimum number of parking spaces and modified the requirements in part by allowing the hotel and retail to share the available

Modified Parking Requirements for the D'Orsay Hotel

	Requirement	Gross Floor Area (GFA)	# of Spaces Required	Cost per Space	Total Cost (millions)
Generic Requirements					
Retail	4 spaces/1,000 square feet GFA	35,000 square feet	140	$16,000	$2.24
Hotel	1 space/room	162 rooms	162	$16,000	$2.59
Total	--	--	**302**		**$4.83**
Revised Requirements					
Retail	3 spaces/1,000 square feet GFA	35,000 square feet	105	$16,000	$1.68
Hotel	0.70 spaces/room	162 rooms	113	$16,000	$1.81
Total	--	--	**218**		**$3.49**
Revised Requirements and In-Lieu Fees					
Retail & Hotel On-Site	N/A	N/A	162	$16,000	$2.59
Retail & Hotel Off-Site	N/A	N/A	56	$3,000	$0.168
Total (With In-Lieu Fees)	--	--	**218**		**$2.76**

spaces. The plan reduced the retail parking space required to three spaces per 1,000 square feet. The hotel's valet parking system allowed the reduction of parking requirements for the hotel space, to 113 spaces for the 162 rooms. These modifications reduced the number of required spaces by 84.

However, parking construction costs still made the project financially infeasible. Even with the revised requirements, the 218 parking spaces for this project would cost $3.49 million to build. Upholding its mission to encourage urban revitalization, the city of Long Beach Redevelopment Bureau agreed to further adjust the parking requirements by charging in-lieu fees in places of 56 of the required spaces. The in-lieu fee was $3,000 per parking space plus an additional $50 per space per month to cover parking operating and maintenance expenditures. The city is obligated to provide those parking spaces near the hotel.

D'Orsay Hotel

Profile:
- Boutique hotel with retail space on former downtown parking lot
- 162 parking spaces, 47 percent less than typical requirement

Strategy:
- Parking study to assess market demand
- Shared parking
- In-lieu fees to provide off-site parking

Benefits:
- Eliminating unnecessary parking saved $2 million in construction costs, making project financially feasible
- Provides new shopping and work opportunties downtown
- Adds $300,000 in new tax revenues annually, to be used for further revitalization projects

As shown in the accompanying table, the revised parking requirements decreased the developer's parking construction costs by over $2 million, with $730,000 of the savings coming from the in-lieu fee arrangement. This reduction made the entire project financially feasible. These cost savings significantly improved the projected financial net returns for the proposed project and ultimately facilitated revitalization of the surrounding area.

The hotel is expected to generate approximately $300,000 annually in additional property tax revenues for the city. Because this property is in an economically troubled area qualified to receive special assistance as a "California Redevelopment Project Area," the property tax revenue generated from the project will be directed back into the area for further redevelopment and infrastructure improvements. In addition, the state will receive revenues from California's 8.25 percent sales tax, and the city will receive revenues from the 10 percent hotel tax. The D'Orsay Hotel will give Long Beach residents an active and pedestrian friendly downtown with multiple amenities. Infill redevelopment like the D'Orsay Hotel and other projects may help to reduce development pressures on outlying areas and encourage additional redevelopment.

This successful redevelopment was made possible by several elements:

- The city of Long Beach's flexibility and recognition that parking is expensive and consumes valuable land. This enabled the developer to negotiate the reduced parking requirements and in-lieu fees that made the project feasible.
- Combining two types of innovative parking strategies (shared parking and in-lieu fees). This was necessary to make the development

project financially feasible.

- Conducting a development-specific traffic study to estimate the number of parking spaces needed for development. The study of other downtown Long Beach hotels showed that applying the city's parking standards would have resulted in an excess supply of parking at the D'Orsay Hotel.

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A Framework for Projecting the Potential Statewide Vehicle Miles Traveled (VMT) Reduction from State-Level Strategies in California

March 2017

A White Paper from the National Center for Sustainable Transportation

Marlon Boarnet, University of Southern California

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EXECUTIVE SUMMARY

The California Global Warming Solutions Act of 2006 (Assembly Bill 32) created a comprehensive, multi-year program to reduce greenhouse gas (GHG) emissions in the state to 80% below 1990 levels by 2050. With the recent passage of Senate Bill 32, the State of California has adopted an additional target of reducing greenhouse gas emissions to 40% below 1990 levels by 2030. To meet these goals, analysis shows that California will need to achieve an additional 7.5 percent reduction in light-duty vehicle miles of travel (VMT) by 2035, and an additional 15 percent reduction in light-duty VMT by 2050.

The California Air Resources Board (ARB) is thus considering a wide range of strategies for the 2016 Scoping Plan Update that focus on reducing demand for driving. These strategies fall into four general categories: Pricing, Infill Development, Transportation Investments, and Travel Demand Management Programs. The State has the ability to directly implement some of these strategies through state policy; for other strategies, the State can adopt policies that encourage or require the implementation of the strategy on the part of regional agencies, local governments, and/or the private sector.

In this paper, we consider the evidence available and assumptions needed for projecting statewide VMT reductions for each category of strategies. Our goal is to provide a framework for projecting the magnitude of reductions that the state might expect for the different strategies. This framework helps to illuminate the sequence of events that would produce VMT reductions and highlights important gaps in knowledge that increase the uncertainty of the projections. Despite uncertainties, the evidence justifies state action on these strategies: the available evidence shows that the strategies considered in this paper are likely to reduce VMT if promoted by state policy.

We do not in this paper examine the potential co-benefits of VMT-reduction strategies, including health, equity, and other benefits, but the evidence of these benefits is also strong and further justifies state action.

Strategy Category	**State Policy to VMT Link**	**Effect on Individual VMT**	**Potential for Statewide Implementation and Adoption – Strategy Extent**
Pricing	Most direct	Strong effect Solid evidence	Can be applied state-wide (fuel taxes, VMT fees) and in targeted areas (link pricing, cordon pricing, parking pricing). Most effective where individuals have good alternatives to driving. Strategies have equity implications. Generates revenues that can be invested in transportation system.
Infill Development	Direct and indirect	Moderate effect Solid evidence	Most applicable in metro areas. Will affect populations living and working in infill areas. May depend on changes in local land use policy. May require financial incentives. Land use changes and VMT effects accrue over the long term.
Transportation Investments			
Bike/Ped	Direct and indirect	Small effect Moderate evidence	Most applicable in metro areas. Will affect populations living and working where investments are made. May depend on changes in local investments. May require financial incentives. May require package of strategies. Many co-benefits.
Transit	Direct and indirect	Small effect Moderate evidence	Most applicable in metro areas. Will affect populations living and working where investments are made. May depend on changes in transit agency action. May require financial incentives. May require package of strategies. Many co-benefits.
Highways	Direct	Strong *induced VMT* effect Solid evidence	New capacity that reduces travel times leads to VMT growth. Effect is greatest in congested areas. Operational improvements that reduce travel times can also induce VMT.
Transportation Demand Management	More indirect	Moderate effect Solid evidence	Most applicable in metro areas. Generally implemented by large employers in response to state or local requirements or financial incentives. Some applications appropriate for rural areas.

Introduction

The California Global Warming Solutions Act of 2006 (Assembly Bill 32) created a comprehensive, multi-year program to reduce greenhouse gas (GHG) emissions in the state to 80% below 1990 levels by 2050. With the recent passage of Senate Bill 32, the State of California has adopted an additional target of reducing greenhouse gas emissions to 40% below 1990 levels by 2030.

The AB 32 Scoping Plan, first adopted in 2008, outlines how the state will meet these targets. In 2015, Governor Brown directed the California Air Resources Board (ARB) to update the Scoping Plan. The transportation sections of previous Scoping Plans were primarily focused on cleaner fuels and cleaner vehicles; VMT reduction strategies were limited to continuing implementation of SB 375. With the 2016 Scoping Plan Update, the California Air Resources Board (ARB) is considering a wider range of strategies that focus on reducing demand for driving. ARB projects that vehicle miles of travel (VMT) will grow 11 percent from today to 2030. A recent visioning scenario analysis done by ARB for the Mobile Source Strategy, which will be incorporated into the updated Scoping Plan, concluded that in addition to existing initiatives such as continued implementation of SB 375 and improvements in vehicle and fuel technology, California will need to achieve an additional 7.5 percent reduction in light-duty VMT by 2035, and an additional 15 percent reduction in light-duty VMT by 2050, in order to meet the State's overall GHG goals.[1]

State-level policies, priorities, and investments will have a profound effect on trends in VMT and are critical to shifting the state from the projected increases in VMT to the needed reductions in VMT. There is extensive evidence on strategies that can reduce VMT, as documented in a series of research briefs we produced for ARB.[2] In response to SB 375, the State has already taken action to implement some of the strategies that research shows are likely to reduce VMT. State-funded grant programs, for example, provide funding and financing for infill development, transit, bicycle facilities, and other changes to the built environment that will enable Californians to reduce their driving. At the same time, it is important to recognize that many long-standing state policies are likely to contribute to increased VMT trends even though this was not their primary objective. Most notably, decades of expansions of the state highway system, declines in the inflation-adjusted state gas tax, and financial and policy barriers to infill development and housing production have contributed to an upward VMT trend.[3] State policies often work against each other in influencing how much the state's residents drive.

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[1] Mobile Source Strategy, May 2016. Available at:

[2] Senate Bill 375 - Research on Impacts of Transportation and Land Use-Related Policies. Available at: https://arb.ca.gov/cc/sb375/policies/policies.htm

[3] For a summary of the evidence on how highway capacity increases lead to move VMT, see the ARB policy brief on highway capacity and induced travel, at
https://www.arb.ca.gov/cc/sb375/policies/hwycapacity/highway_capacity_brief.pdf.
https://www.arb.ca.gov/cc/sb375/policies/hwycapacity/highway_capacity_brief.pdf.

The strategies for reducing driving that the State is considering for the Scoping Plan Update fall into four general categories: Pricing, Infill Development, Transportation Investments, and Travel Demand Management Programs. The State has the ability to directly implement some of these strategies, particularly pricing and some infrastructure strategies, through state policy and direct investment. For other strategies, the State can adopt policies that encourage or require the implementation of the strategy on the part of regional agencies, local governments, and/or the private sector. Infill development, for example, depends largely on local land use policies. For some strategies, such as bicycle infrastructure, state policy can both directly and indirectly influence its implementation.

Projecting the state-wide impact of state policy on VMT thus depends on two components: the "strategy effect," the effect of the strategy, when implemented, on the behavior of Californians and the amount that they drive; and the "strategy extent," the extent of the implementation of the strategy across the state in response to state policy and other forces. The evidence base on strategy effect is strong for most of the strategies under consideration: we can be confident that, if implemented, these strategies will produce a reduction in VMT, even if the magnitude of that reduction is uncertain. In contrast, the evidence on how to increase the strategy extent is often more limited.

Strategy Effect and Strategy Extent

Strategy Effect: The strategy effect is how a strategy (or policy) would change VMT. For example, if the fuel tax in the state were increased by ten percent, how would one driver's VMT change?

Strategy Extent: Strategy extent is how many drivers (or persons) can or would be affected by a strategy. For example, if the State offers incentives for infill development, how many more infill units will be built, and hence how many persons are affected by the strategy?

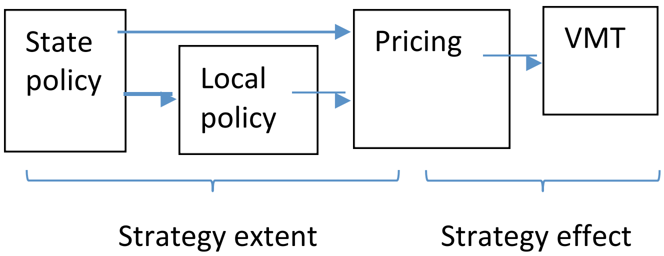
We can simplify by imagining that the overall policy impact is the strategy effect multiplied by the strategy extent.

For example, the influence of state subsidies or affordable housing policy on the actions that local governments take with regard to providing more infill development is sometimes debated, suggesting a need for more research on actions the state could take to foster more infill development. The existing evidence base, however, clearly shows that increased infill development leads to reduced VMT. For infill development, the question is not whether infill development would lead to reduced driving – it will – but rather which state policies would lead to more infill and, if those policies are implemented, how much would VMT be reduced. This is only one example; we discuss the difference between strategy effect and strategy extent for all four categories of policies that are covered in this document. In this paper, we consider the evidence available and assumptions needed for projecting statewide VMT[4] reductions for each category of strategies. Our goal is to provide a framework for at least roughly projecting the magnitude of reductions that the state might expect for the different strategies. The projection methods differ for each strategy depending on its "causal chain" – the sequence of events triggered by state policy that ultimately produce reductions in VMT, including both strategy extent (the causal chain from state policy to strategy implementation) and strategy effect (the causal chain from strategy implementation to VMT reduction). The form in which each strategy effect is reported in the literature also determines the projection method; in discussing strategy effect we rely on our reviews of the evidence base as reported in the ARB Research Briefs, mentioned above. We also outline the critical gaps in knowledge, data, or methods that must be filled before more robust projections are possible. California has staked a cutting-edge position with its GHG reduction framework, and that gives the state an opportunity to push our knowledge base forward. By highlighting knowledge gaps we are noting areas where California can continue and extend its tradition of leadership in environmental policy and environmental science.

We do not in this paper examine the potential co-benefits of VMT-reduction strategies, though they are potentially substantial. Reducing VMT not only reduces GHG emissions, it also reduces emissions of pollutants that harm human health as well as agricultural productivity and natural habitats. Infill development coupled with investments in transit services and bicycle and pedestrian infrastructure expands transportation options, reducing the need for owning a private vehicle and the financial burden that comes with it for lower-income households. Evidence of the benefits of VMT-reduction strategies for human health, social equity, the environment, and the economy is strong, and it further justifies state action to promote these strategies.

[4] For most of the strategies we examine here, the available research examines the effect of the strategy on VMT or other aspects of travel behavior rather than GHG emissions. While VMT reductions translate relatively directly into GHG emissions reductions, other factors may come into play. If, in addition to VMT reductions, the strategy also leads to changes in driving speeds (not just averages but distributions of speeds over the course of trips) or changes in the types of vehicles Californian's drive, then the conversion to GHG emissions is less straightforward. Infill development, for example, might reduce driving distances but also encourage smaller vehicles and produce more congestion and thus lower speeds. For the most part, the literature provides little basis for developing more nuanced conversions of VMT to GHG emissions for these strategies.

1. Pricing



Pricing is a particularly promising policy tool to reduce VMT and associated GHG emissions, for two reasons. First, the effect size from pricing interventions to VMT is larger than the effect size for other policy or planning tools. Second, pricing can be applied to a broad base, and state action can be particularly effective here. In other words, pricing can achieve a broad strategy extent quickly. Recall that the effect of a policy is the effect size (e.g. the amount that a driver's VMT would be reduced if the policy were applied to that driver) multiplied by the number of drivers exposed to the policy.

Pricing revenues can be used to expand non-automobile travel options, making the pricing policies themselves more effective at VMT reduction. Similarly, pricing policies can be used to address equity concerns, for example by expanding bus service, providing pedestrian or bicycle improvements, or mitigating environmental impacts in low-income neighborhoods.

Pricing also has the advantage of raising revenue to fund needed transportation projects. Statewide, our cities and counties have transportation needs that outstrip available revenue. For example, the State Transportation Plan identifies a $294 billion funding gap – funding only 45 percent of the State's transportation system needs through 2020.[5] Pricing and vehicle fees can fund infrastructure improvements, manage congestion, and maintain roadways while also improving air quality and better manage our transportation infrastructure.

There are several different ways to use pricing. We define those briefly here:

Link Tolls: Charge a toll to drive on a portion of a highway. The toll typically varies with congestion levels. Examples include the high-occupancy toll lanes on San Diego's SR-125 and Los Angeles I-110, and congestion priced toll lanes on SR-91 in Orange County. In the San Diego and Los Angeles examples, the toll adjusts based on traffic levels (more traffic implies a higher

[5] See http://www.dot.ca.gov/hq/tpp/californiatransportationplan2040/Final%20CTP/CTP2040-Appendices-WebReady.pdf.

toll) while the toll on the SR-91 in Orange County is based on time of day (peak periods have higher tolls.)[6]

Cordon Tolls: Charge a toll to cross into a downtown central business district or other congested area. There are currently no examples of cordon toll pricing in the U.S. Well known international examples of cordon tolls include London's toll ring, around the center of the city, and the cordon toll in Singapore.

VMT fees: Drivers are charged a fee based on miles driven (VMT). Oregon launched a VMT fee pilot experiment which enrolled drivers in pilot programs to test replacing the state's fuel tax with a VMT fee. California launched a similar pilot in 2016.[7] In 2008-2010, the University of Iowa led a national pilot program that examined VMT fees in lieu of fuel taxes in twelve locations. No VMT fee has moved beyond the pilot/study phase in the U.S.

Fuel taxes: Fuel taxes are applied by every state in the U.S. and the federal government. At-the-pump fuel taxes are assessed on a cents per gallon basis, and so are not adjusted for inflation. A relatively minor exception is cases where sales taxes are also applied to per-gallon fuel taxes. Increased fuel efficiency implies that persons can drive more per gallon, hence fuel taxes raise less revenue per mile driven as vehicle fuel efficiency increases.

Parking prices: There are many parking pricing schemes, from fixed-priced street meters to workplace parking cash-out schemes that offer employees cash in lieu of subsidized free parking to policies that charge employees or non-work travelers for parking to real-time metered parking prices that adjust to equilibrate supply and demand. All have been applied in California. To date, parking pricing policy in the state has been exclusively the domain of local governments, though AB 744 reduced parking space requirements statewide for affordable senior housing.[8]

Pay-as-you-go insurance: This policy proposes to change vehicle insurance from a monthly or six-month fee, which is typically assessed independent of driving, to a per-mile fee.

Freight low emission zones: This proposal would establish low emission zones, usually near residential areas, where trucks would either have to use low emission technology or pay a fee. The prospect of combining pricing with careful land use considerations is a promising way to

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6 Some highways in California use tolls that do not vary with time of day or congestion. The toll roads in south Orange County (portions of SR 73, 133, 241, and 261) have flat rate pricing. The tolls on those lanes were not designed to manage congestion, but are solely a financing tool. There is little evidence on whether and how flat-rate tolls reduce driving, although one can infer that the price effect may be similar. We focus our attention on congestion tolls, which bring the added benefit of congestion management and for which the evidence base is larger.

7 See https://www.californiaroadchargepilot.com and, for a related discussion, Marlon G. Boarnet, "Policy Approaches for California's Transportation Future," California Central, 2016, available at http://californiacentral.usc.edu/wp-content/uploads/2016/06/CA-Central-transportation-6-13-16.pdf.

8 See https://leginfo.legislature.ca.gov/faces/billNavClient.xhtml?bill_id=201520160AB744.

address environmental justice implications of truck emissions that disproportionately affect low-income communities. Yet this policy, because it is a hybrid of pricing, emission technology requirements, and land use patterns that would interact with the transportation network, is less a pure pricing strategy. Also, the response of truck traffic to pricing depends on the nature of driver contractual relationships with trucking companies and hence is best informed by evidence that is specific to pricing and trucking. For those reasons, we believe the existing pricing evidence, largely from passenger travel and mostly from pure pricing experiments or policies, cannot be as easily applied to low emission zones. We note, though, that the same basic theory applies to trucks as to passengers – higher prices would discourage driving activity in the locations and at the times for which the price is higher – and it is only the magnitude and detailed effect of a low emission zone that we do not discuss further here.

Strategy Effect: Impacts of Pricing on Individual or Household VMT

The available evidence on effect sizes can be grouped into four categories: (1) link and cordon tolls, (2) VMT fees, (3) Fuel prices (and hence fuel taxes), and (4) parking pricing. We know of no available evidence on the effect size of pay-as-you-go insurance, and for the reasons mentioned above we believe that freight low emissions zones, while promising, should be a separate topic of study.

Importantly, both theory and evidence suggest that the effect sizes are similar across the different pricing tools for which data are available. A price is a price, and, as an approximation, drivers should not care if they pay a dollar to buy gas, drive on the highway, or park; the effect of the price on driving might be quite similar for those different policies. As it turns out, the empirical range of pricing effect sizes across different policies are similar, and that allows some confidence to interpret from the existing evidence base to policies, such as pay-as-you-go insurance, for which there is not currently an effect size evidence base. It is reasonable to assume, for example, that pay-as-you-go insurance would look to drivers like a VMT fee, and hence that the VMT fee evidence would apply. As mentioned above, freight low emission zones, because they are a hybrid of pricing, emission technology requirements, and land use, would require additional evidence not discussed here.

The range of effect sizes in Table 1 is large in some cases (e.g. the long-run elasticity of VMT with respect to fuel price.) We note that a conservative estimate of an elasticity would be -0.1, which is toward the low end of the range for link and cordon tolls and for fuel prices. Similarly, results from the Oregon VMT fee pilot program suggest that replacing a fuel tax with a VMT fee in a revenue-neutral way could reduce VMT by 11 to 14 percent. Overall, we suggest that an elasticity of VMT with respect to pricing of -0.1 is a conservative estimate that might be used to apply across different pricing programs.

Most of the evidence on parking pricing relates price to the demand for parking spaces, and inferring a VMT elasticity for parking pricing can be more difficult. However, a recent program in San Francisco, SF*park*, adjusts on-street parking prices based on occupancy – raising the metered price for an on-street parking space when more than 80 percent of the spaces on a block are occupied (Millard-Ball, et al., 2014). Recent studies of SF*park* suggest that the program and it's demand-based pricing may reduce cruising for parking by 50 percent (Millard-Ball, et al., 2014).

Table 1: Effect Sizes for Pricing Policies

Pricing Policy	**Elasticity (unless otherwise noted)**	**Source**
Link and Cordon Tolls	-0.1 to -0.45	ARB policy brief on road user pricing
VMT fees	-11% to -14.6% reduction from shifting gas tax to VMT fee	ARB brief on road user pricing, from Oregon VMT fee experiment
Fuel prices	-0.026 to -0.1 (short-run) -0.131 to -0.762 (long-run)	ARB brief on gas price
Parking pricing	-0.3 for demand for parking spaces	ARB parking pricing and parking management brief

Source: ARB policy briefs, at https://arb.ca.gov/cc/sb375/policies/policies.htm

Strategy Extent: Impact of State Policy on Pricing

Pricing can be implemented in ways that achieve broad strategy extent. VMT fees and fuel prices can affect every driver in the state. Again, this paper provides a framework for at least roughly projecting the magnitude of reductions that the state might expect for the different strategies. There are few other State actions that could similarly achieve universal coverage without collaboration or leadership from a broad range of municipal governments. Link and cordon tolls have typically been the purview of local governments, and because such congestion pricing is applicable in congested locations, link and cordon tolls would likely continue to be a local government activity. But Caltrans is the owner operator of the state highway system, and so the State has many opportunities to encourage link pricing, in particular, on state highway routes. The State could, for example, offer subsidies or incorporate pricing more explicitly into the SB 375 Sustainable Communities Strategy (SCS) process. Similarly, the State could work closely with local governments and county transportation agencies to encourage innovative programs that use pricing while also addressing the equity questions that are raised by road or VMT pricing. Other efforts, such as pay-as-you-go insurance, could be implemented through State action. Overall, State action in pricing can have a broad extent and can take effect quickly, as opposed to land use policies which would have a sizeable effect but over a longer period of time as the built environment is modified.

The steps to use in quantifying the impact of State-level pricing strategies on VMT are shown in Table 2 below. Table 2 has four panels, for fuel taxes, VMT fees, link or cordon tolls, and pay-as-you-go insurance. Parking pricing is not shown, because the link from those policies to VMT has been less studied, although the nascent evidence from SF*Park* is promising and suggests that priced parking can substantially reduce the amount that drivers “cruise” to find parking spaces (Millard-Ball, Weinberger, and Hampshire, 2014).

Note that the data on the fuel prices gives direct estimates of the effect of changes in fuel prices (from, e.g., tax changes) on VMT; relatively few assumptions are needed compared to other policies that we discussed in this paper. The data on VMT fees similarly require few assumptions, although the state would require advances in modeling the location of traffic across the state and into and from neighboring states for a complete analysis. While the VMT fee data are from pilot programs, those programs and the current pilot in California provide an opportunity to get good evidence on the effect of VMT fees on driving. Tolls require an assumption about the amount of driving that would be diverted to routes or times of day that are not tolled, and the evidence on that is more limited. Leape (2006) estimates that a quarter of the traffic reduction within the London cordon toll ring was diverted to other routes. Pay-as-you-go insurance requires an assumption that the elasticities from VMT fee or fuel tax studies apply, but such as assumption is theoretically sound. Overall, quantifying the effect of pricing on driving requires relatively few assumptions compared with other policies.

Table 2: Assumptions and Data Needed to Estimate Effect of State-Level Pricing Strategies on VMT

Panel A: Fuel Prices			
Step	**Assumptions or Data Needed**	**Validity of Assumption (Scale: 1 = poor, 5 = excellent)**	**Future research tasks to strengthen assumptions and data**
1. Quantify percentage increase in fuel price	Compare proposed tax increases to existing fuel prices	Validity = 5 (excellent) Data are available on fuel prices, by state and for areas within the state. Fuel prices vary over time, often substantially so, and so analysts would have to address that variation over time in assessing the "base" (before-tax-increase) fuel price.	Data are available.
2. Determine population that will be affected by tax	Fuel taxes typically affect everyone in the state	Validity = 4 (good) to 5 (excellent) The literature on passenger travel and fuel taxes gives good evidence; less literature on freight travel and fuel taxes	To refine future estimates, the state can study how freight travel responds to fuel taxes and whether the strategy effect, from mostly passenger vehicle studies, applies to freight traffic.
3. Apply strategy effect to affected population	Use elasticity of -0.1 (minus 0.1), per discussion above	Validity = 4 (good) to 5 (excellent)	Studies on the effect size are high quality. Future research should examine how variation in fuel prices over time affect VMT, given the high month-to-month and year-to-year volatility in fuel prices. Over the long-term, taxes might be designed to adjust in the opposite direction of market fuel price variation, holding at-the-pump fuel prices more constant.

Panel B: VMT Fee			
Step	**Assumptions or Data Needed**	**Validity of Assumption (Scale: 1 = poor, 5 = excellent)**	**Future research tasks to strengthen assumptions and data**
1. Assess extent of VMT fee	Fees could be statewide or for sub-sets of state	Validity = 4 (good) to 5 (excellent)	Traffic will cross borders if VMT fee does not apply to entire state, and even if statewide, some traffic will enter and leave the state. Some improvement in statewide travel modeling could be needed to account for border effects.
2. Quantify whether VMT fee will be revenue neutral	Assumption about revenue neutrality will translate to amount of the VMT fee	Validity = 4 (good) to 5 (excellent)	Continue pilot programs to understand how revenue responds to fee levels
3. If fee is revenue neutral, apply evidence on effect	Oregon pilot program suggests revenue neutral VMT fee will reduce driving by 11 to 14 percent	Validity = 3 (fair) to 4 (good)	Evidence from California pilot program (now underway) should be used to supplement the Oregon evidence

Panel C: Link or Cordon Tolls			
Step	**Assumptions or Data Needed**	**Validity of Assumption (Scale: 1 = poor, 5 = excellent)**	**Future research tasks to strengthen assumptions and data**
1. Estimate toll amount and resulting change in cost of travel	Data on pre-existing travel needed -- use estimates of number of persons passing link from Caltrans link travel data (e.g. AADT), and estimate pre-toll dollar cost of travel based on average trip lengths	Validity = 3 (fair) Data on link travel can be obtained, but the literature does not clarify if the time-cost of travel should be included in the base amount to analyze change in travel cost.	California has existing toll lanes, and data from those lanes should be used to get better information about the appropriate measure of the population affected and how to measure toll costs for purposes of applying the elasticity of the strategy effect.
2. Estimate reduction in traffic in tolled area	Apply elasticities, which for link and cordon tolls will usually predict reduction in traffic in the tolled area, not reductions in VMT	Validity = 3 (fair) to 4 (good)	Continue research, particularly on cordon tolls which have not been implemented in U.S. and so require research from international settings
3. Estimate diverted traffic	Estimate the amount of driving that moved from the tolled area to a different route	Validity = 2 (poor)	The evidence on how tolls divert traffic is limited. Leape (2006) estimates 1/4 of reduced traffic in London cordon toll was diverted to other routes. Toll lane price changes in California can provide an opportunity for before-after studies of traffic diversion.
4. Estimate VMT reduction	Use data or assumptions about average trip lengths (before tolling), reduction in trips, and the fraction of trips diverted to get estimate of reduced VMT.	Validity = 2 (poor) to 3 (fair)	Diverted traffic is the weakest link here, and future research should focus on how toll price changes divert traffic.

Panel D: *Pay-As-You-Go-Insurance*			
Step	**Assumptions or Data Needed**	**Validity of Assumption (Scale: 1 = poor, 5 = excellent)**	**Future research tasks to strengthen assumptions and data**
1. Assess Population Affected by Pay-As-You-Go Insurance	If program is voluntary, use data from pilot programs or other markets to assess how many drivers would opt for pay-as-you-go insurance	Validitity = 3 (fair)	There is very limited experience with pay-as-you-go insurance. Pilot programs are advisable to understand the "take up" rate for this insurance product, particularly if pay-as-you-go competes with traditional flat-rate insurance.
2. Quantify percentage increase in cost of driving	Compare proposed pay-as-you go fees (per mile basis) to existing per-mile driving costs	Validity = 4 (good) to 5 (excellent)	Data are available on per-mile driving costs.
3. Determine effect size for drivers	Assume pay-as-you-go strategy effect is similar to VMT fees or fuel taxes, hence elasticity = -0.1	Validity = 4 (good)	The price effect is likely very similar to VMT fees or fuel taxes which change the marginal (e.g. per-mile) cost of driving. Pilot programs should be developed to confirm this theoretical prediction.
4. Apply effect size to affected population	Direct calculation from steps above	Validity = 4 (good) to 5 (excellent)	Again, if pay-as-you-go competes with flat-rate insurance, understanding consumer demand for pay-as-you-go will be important

Policy Considerations for Pricing

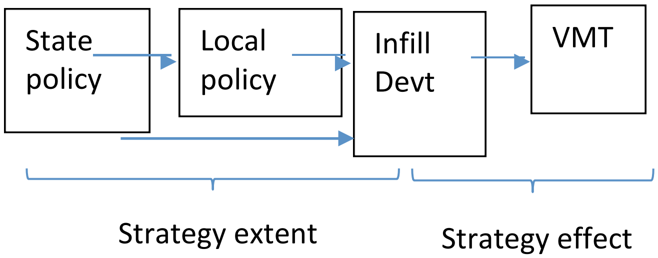
Pricing policies generate a revenue stream. That is an important potential benefit. Pricing also brings substantial policy advantages beyond VMT reduction. Pricing revenues can be used to expand non-automobile travel options, making the pricing policies themselves more effective at VMT reduction. Similarly, pricing policies can be used to address equity concerns, for example by expanding bus service, providing pedestrian or bicycle improvements, or mitigating environmental impacts in low-income neighborhoods.

Sales tax finance has become the primary means of transportation finance in most large California metropolitan areas. The sales tax is regressive, meaning that sales taxes are a larger fraction of income for lower income persons than for high income persons. Sales taxes are paid by persons irrespective of their use of roads, raising both efficiency and equity issues. From an efficiency perspective, sales taxes provide no nexus between revenues raised and use of the transportation system. From an equity perspective, sales taxes are paid by persons who do not use the system, with lower income persons paying a larger share of their income in sales taxes. Schweitzer and Taylor (2008) compared the toll-road finance of the SR-91 in Orange County with an equivalent (revenue-neutral) sales tax finance and found that under reasonable assumptions toll road finance would be more equitable, and that sales tax finance could in many cases place a larger burden on lower income households. Pricing policies have the prospect of providing much needed revenues for transportation, in ways that build a link between use of the system and financing while being more equitable than current transportation finance policies.

Pricing policies will be more effective in reducing VMT when and where there are easily available non-automobile options. Hence policymakers should be aware that implementing pricing in locations with many travel options, or with a plan to expand travel options, would be a preferred approach. Fortunately, congestion and parking pricing would likely be implemented first in congested urban areas or in locations where land values are high, which are typically the same locations with non-automobile transportation options.

While evidence suggests that state intervention to increase the price of driving is highly likely to yield reductions in VMT, estimating a more precise degree of impact from state actions – for the purposes of modeling by ARB and others to quantify anticipated VMT reductions from specific strategies – would require further analysis. Table 2 presents an outline of suggested steps for gaining more precision and clarity in this estimation.

2. Infill Development



Land use in California has long been a local domain, but many State actions and laws, such as Regional Housing Needs Assessment (RHNA) allocations and the California Environmental Quality Act (CEQA) influence outcomes. The State also provides subsidies, such as the Affordable Housing and Sustainable Communities (AHSC) program, which can assist localities that are pursuing infill development. State policy, and the link from state policy to local policy, is important. Yet the evidence is most clear on the strategy effect, the effect from land uses associated with infill development to VMT.

Many land use policies have the potential to reduce VMT. The ARB policy briefs discuss the effect of residential density, employment density, land use mix, street connectivity, distance to transit, regional accessibility to jobs, and jobs-housing balance. The literature provides strong evidence that persons who live in more centrally located, dense, mixed use developments with walkable infrastructure and near transit options will drive less. The effect of land use on reducing driving is, at least in part and possibly in largest part, causal, meaning that when persons move to a mixed-use transit-oriented or walkable neighborhood, the land use causes them to drive less (Cao, Mokhtarian, and Handy, 2009; National Research Council, 2009; Duranton and Turner, 2016.)

We will first discuss that body of evidence on the effect of land use and infill development on VMT (i.e. the strategy effect), then turn to the upstream question of the effect of state and local policy on infill development (i.e. the strategy extent). Note that policies to promote infill development are policies that will place more residents in locations that are more accessible to jobs and transit, with higher densities, more mixed land uses, and better street connectivity. Hence we use "infill development" as a summary measure of land use, both because it is a meaningful measure and because it clarifies policy approaches to metropolitan area planning. State policies can affect the prospects for infill development, and recent state actions (e.g. SB 743) are attempts to measure impacts in ways that change the attributed traffic/transportation impact of infill versus outlying development to more appropriately give environmental credit to infill projects that will reduce VMT in large metropolitan areas.

Strategy Effect: Impact of Infill Development on Individual or Household VMT

The first question is how to measure the effect of infill development on individual or household travel behavior.[9] We suggest that the best proxy measure for infill development is regional access to jobs. Both lay audiences and policy-makers often think about residential density when measuring land use, because density is intuitive (persons or dwelling units per land area) and easy to measure. Yet residential density is among the land use variables with the weakest links to VMT. The strategy effect size of residential density on VMT has an elasticity from -0.05 to -0.12, meaning that if density doubled, household VMT would be reduced by from 5 to 12 percent. The strategy effect size of regional job access is twice as large – an elasticity of from -0.13 to -0.25.[10] This implies that density alone is a less meaningful metric for VMT reduction than proximity to job centers. However, in practice, increased density is likely also needed to increase the number of households near job centers.

Not only is the strategy effect of density smaller than the strategy effect of regional job access, regional job access is a policy with a potentially broader strategy extent. Doubling residential density would be, in most locations, outside of the realm of feasible policy changes. As we show in the appendix, infill policies can double a household's regional job access in California's urban areas simply by providing housing options that are closer to job concentrations, and are likely feasible in ways that doubling density is usually not. Overall, regional job access is a much better measure of the strategy effect and the policy possibility (strategy extent) of infill development.

Improving regional access to jobs implies a planning focus on where, in the metropolitan area, new growth occurs. Would new growth be near the center, where more jobs are located and hence where access to jobs is good, or on fringe, where access to jobs is weaker?

A typical measure of jobs access is called a "gravity variable." Most gravity variables are a sum of the jobs that a resident can reach from their household, multiplying jobs by the inverse of the distance from a household's home to the job. Jobs that are closer to where a household lives count for more, and jobs farther away count for less. There are different mathematical formulations in the literature. Some authors sum only jobs within five miles of a household (for an application, see Salon, 2014, or Boarnet and Wang, 2016.) Other studies (e.g. Zegras, 2010) use distance from the downtown by itself, noting that a household's distance from downtown is strongly correlated with gravity variable measures of job access. For now, note that distance from downtown (e.g., whether a household live 10 miles from downtown, or 20 miles from downtown) is easier to measure than a gravity variable that sums all jobs in the metropolitan

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[9] Often times the academic literature looks at household travel, because family members within a household can trade trips, such that one person might go to the store while the other does the banking, or vice versa. Using household data allows researchers to treat the household as the behavioral unit. When the overall literature is summarized, as we do here, the disaggregate data are typically from studies of individual travelers or drivers, or from households.

[10] See the ARB Research Briefs on residential density and regional access to jobs, at https://www.arb.ca.gov/cc/sb375/policies/density/residential_density_brief.pdf and https://arb.ca.gov/cc/sb375/policies/regaccess/regional_accessibility_brief120313.pdf, respectively.

area weighted by the inverse of the distance from the household to those jobs. Having said that, much of the literature has used gravity variables, and so we discuss gravity variables first.

Figure 1 shows gravity variable measures of job access for the greater Los Angeles region, in five categories, or quintiles. Figure 1 shows that locations near downtown have the best job access, and job access declines as one moves further from downtown. The ARB policy brief for regional job accessibility suggests an elasticity of VMT with respect to job access ranging from -0.13 to -0.25, meaning that if job access were doubled (a 100 percent increase), household VMT would decline by from 13 to 25 percent. Note that high end of the range of this strategy effect is almost exactly the same as what you would get if you used a simpler measure of distance from downtown, for which the ARB policy briefs suggest an effect size of 022 to 0.23, meaning that if a household moves from 10 to 20 miles away from downtown (a 100 percent increase in their distance to downtown), their VMT would increase by 22 to 23 percent.[11]

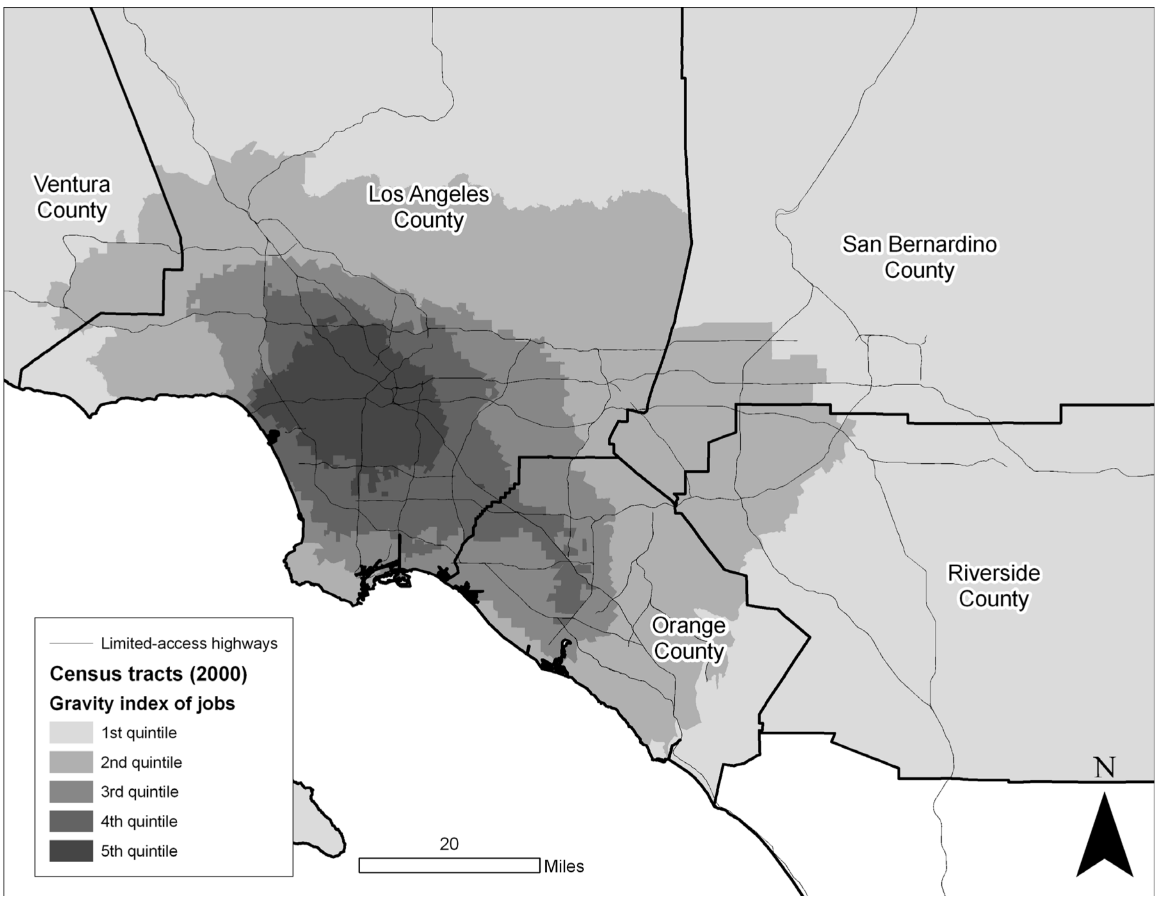

Figure 1. Gravity Variable of Regional Access to Jobs, metropolitan Los Angeles, 2000 (reprinted from Boarnet, Houston, Ferguson, and Spears, 2011, Figure 7.3)

[11] See the ARB Research Briefs on regional access to jobs, https://arb.ca.gov/cc/sb375/policies/regaccess/regional_accessibility_brief120313.pdf.

The strategy effect would measure moving persons (or changing the location of new development) from places with poor to better job access. As an example, the Southern California Association of Governments has proposed to focus almost half of the region's future growth and new development in high quality transit areas, defined as places within a half-mile of fixed-route transit or bus transit with peak-period transit service of 15 minutes or less.[12] Many other metropolitan areas have engaged in scenario planning exercises to simulate changes in growth patterns that would favor infill development. Referring back to the map in Figure 1, the darkest shaded areas have the best job access (they are in the fifth, or highest, quintiles of access.) The next darkest areas are in the fourth quintile, and the next highest areas are in the third quintile, and so forth. Example communities in those areas are shown in Table 3 below.

Table 3: Examples of Municipalities in 3rd, 4th, and 5th Quintile of Regional Access to Employment

Job access quintile [a]	Example neighborhood/municipality
5th quintile (highest job access)	Downtown Los Angeles Hollywood West Los Angeles Crenshaw Echo Park
4th quintile	Santa Ana Orange Fullerton Lakewood La Mirada Southern San Fernando Valley
3rd quintile	North Orange County Covina

An ideal measure of the effect of infill development would measure the effect of changing the location of development on VMT – for example, what would happen if, instead of building new residences near Covina (the third quintile of job access in Figure 1), the Los Angeles region added new residences in communities such as Santa Ana (the fourth quintile of job access) or Echo Park (the fifth or highest quintile of job access.) One method would be to assess, numerically, how much a measure of a household's job access would increase when they locate in, for example, Santa Ana or Echo Park as opposed to Covina. Such a method is outlined in the appendix. This approach would require several computational steps, and for simplicity we do

[12] SCAG's 2016 Regional Transportation Plan projects that 46 percent of new residential growth and 55 percent of new employment growth will be on the three percent of the region's land that is in high quality transit areas. See Southern California Association of Governments, 2016 RTP/SCS, Executive Summary, p. 8, http://scagrtpscs.net/Documents/2016/final/f2016RTPSCS_ExecSummary.pdf.

not go over that here, although we note that the estimated strategy effect computed in the appendix is similar to what we present here using simpler methods.

Rather than use a gravity variable for regional access to jobs, one could use distance from the downtown to approximate the change in the job access measure. Following the example, Covina is approximately 24 miles (driving distance) from downtown Los Angeles, while Echo Park is approximately 4 miles from downtown Los Angeles, a reduction in distance from downtown of 83 percent if infill development could allow a household to locate in Echo Park rather than Covina. Multiplying that change in distance by the 0.22 effect size of distance from downtown, this implies that moving households from Covina to Echo Park could reduce their driving by 18 percent. Using more sophisticated regression techniques, Boarnet and Wang (2016, Table 12, p. 36) predict that a household move across similar distances in the Los Angeles region could be associated with even larger VMT reductions – as large as 33 percent.[13]

We can use the literature, with effect sizes drawn from changes in gravity variables or simpler changes to distance from downtown, to predict the effect of increased infill development. Table 4 gives an illustration of the steps and the data and assumptions needed.

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[13] See Marlon G. Boarnet and Xize Wang, Urban Spatial Structure and the Potential for Reducing Vehicle Miles Traveled, National Center for Sustainable Transportation research report, April, 2016, available at http://ncst.ucdavis.edu/wp-content/uploads/2014/08/04-18-2016-NCST-Urban-Spatial-Structure-Boarnet-4_10_16.pdf, accessed Sept. 24, 2016.

Table 4: Assumptions and Data Needed to Estimate Effect of Infill Development on Household VMT

Step	Assumptions or Data Needed	Validity of Assumption (Scale: 1 = poor, 5 = excellent)	Future research tasks to strengthen assumptions and data
1. Measure land use patterns associated with infill development	Choose a measure that will proxy location in the region, and hence infill policies: Regional job access measures as a gravity variable or distance from downtown	Validity = 3 (fair) to 4 (good) If access to transit and access to non-auto transportation are included elsewhere in the analysis, evidence indicates that remaining land use patterns are correlated with regional job access; the evidence suggests that the size of the strategy effect is very similar whether measured by gravity variables or distance from downtown, even in highly sub-centered metro areas	Develop statewide GIS measures of land use characterized by either (1) distance from metropolitan area downtown, (2) gravity measure of regional access to jobs, or (3) the land use categories developed in research by Salon (2014) which can likely be analogs to regional job access
2. Use data across different locations to proxy infill development – translate infill to changes in a job access gravity variable or changes in distance from downtown.	Need assumptions or information from scenario models about different growth scenarios for metropolitan areas to understand how regional job access would change, and for how many households	Validity = 2 to 3 (poor to fair) There are several scenario tools, but all such tools are possible policy futures. There will be uncertainty regarding the amount of infill development, and we suggest modeling several possible future infill growth scenarios, from aggressive use of infill to somewhat less aggressive, to bound possibilities.	Recommend using or updating the scenario tool developed as part of Salon (2014) for statewide simulations of moves across development types.
3. Use an elasticity of household VMT with respect to regional job access to calculate percentage changes in household VMT	Use regional job access elasticity from ARB regional accessibility brief.	Validity = 4 (good) Job access elasticities vary within metropolitan areas, as demonstrated by Boarnet et al. (2010) and Salon (2014), but regional averages give a good mid-point or average effect.	Use ranges of elasticities from, e.g., Boarnet et al. (2010) or Salon (2014), or adapt and use the scenario tool from Salon (2014)
4. Apply predicted percentage change in household VMT to a base-year measure of household VMT to obtain predicted change in household VMT.	Apply predicted percentage change in household VMT to average household VMT for a metropolitan area or the state.	Validity = 2 to 3 (poor to good) The CHTS has data on household VMT in different locations. These data are available and reliable. The difficulty is understanding where households might have located absent infill policies, a point currently not sufficiently addressed in the literature. Scenario models can be used to assess where households would have lived absent infill policies.	More research on how changes in housing supply in specific locations (e.g. infill) affect residential location choices of households.

Table 4 illustrates four steps, (1) measuring land use patterns, (2) simulating changes in development patterns (e.g. from infill development) and translating those changes in development patterns into changes in a measure of regional job access or distance from downtown, (3) using elasticities in the literature to measure the impact of a change in regional access to jobs (or distance to downtown) on VMT, and (4) apply the predicted change in VMT to a base year level of household VMT.

Table 4 starts with a first step of measuring land use, either with gravity variables or with simpler measures of distance from downtown. Note that the Air Resources Board recently funded research by Salon (2014) which developed statewide categories of neighborhood types, and those neighborhood types might be close approximations to regional job access, and so we add those neighborhood types developed by Salon (2014) to the list of possible regional job access measures. A complementary approach could be based on the California Statewide Travel Demand Model, which has employment data for zones statewide.[14] The second step would assess how changes in the amount of infill development would lead to changes in job access and how many persons (households) would be affected by those changes. We suggest bounding possible amounts of new development in this second step, from a modest amount of infill to aggressive use of infill, relying on local policy expertise to inform how modest and aggressive would be quantified in terms of number of new housing units and hence the number of households affected. Step 3 in Table 4 applies elasticities from the ARB job access policy brief. We note that there is a nascent literature (Boarnet, 2011; Salon, 2014) that gives evidence that the strategy effect of regional job access on VMT varies depending on where, in the metropolitan area, a household lives, but we also note that mid-point or average estimates of the policy effect will both work well and, if anything, understate the VMT effect of infill development.[15] The last step would be to apply the strategy effect (percent reduction in VMT) to the number of households affected by the strategy.

The evidence is consistent and very strong that households that live in more central locations in urban areas drive less. That relationship is very common in the data, and sophisticated studies that attempt to control for household location choices suggest that more central locations with better multi-modal transportation access cause households to drive less (e.g. Duranton and Turner, 2016; Spears, Houston, and Boarnet, 2016.) While we suggest, in Step 4 of Table 4, that the state continue to research *how* different households choose their residential location, and hence which households would move into infill developments, we note that such information will be more important to understand questions of equity (e.g. gentrification and displacement)

[14] See the SB 743 Impact Assessment Web page, at http://www.dot.ca.gov/hq/tpp/offices/omsp/SB743.html. The data available there can provide a basis for measures of employment in zones throughout California, and hence for measures of employment access.

[15] The strategy effect of regional access to jobs might be larger in centrally located areas, implying that using the metropolitan-wide average effects from the ARB policy briefs might understate the VMT-reducing effect of infill development. For a discussion and evidence, see Boarnet et al. (2010) and Salon (2014).

rather than to understand whether households in central locations drive less. The literature provides strong evidence that households in more central parts of urban areas drive less.

Strategy Extent: Impacts of State Policies on Infill Development

While there is strong, evidence-based correlation between infill development and VMT reduction, estimating state-wide VMT effects of State policies to encourage infill development requires additional assumptions about the effectiveness of state policies in making infill development happen. There is still a lack of empirical literature on *how* state policies lead to more (or less) infill development, but the state's existing policy framework, including but not limited to SB 375, provide an opportunity to study how state goals and requirements influence development activity. For now, we note that the state has many policy tools that can influence development.

State Policy Considerations for Infill Development

The state has interests in increasing infill development, and the literature demonstrates that doing so will advance State VMT reduction goals (as well as multiple other State policy priorities). SB 743 changed the traffic impact metric in CEQA, and Governor Brown recently proposed a by-right housing proposal which was not acted upon by the legislature. The state has also recently taken action on auxiliary dwelling units.

More could be done by continued changes in the measurement of impacts required by state legislation (e.g. CEQA), or with legislation that allows (or even requires) streamlined development approval when certain conditions (possibly infill location and/or providing affordable housing) are met. The state could also subsidize infill development, or provide tax reductions, which could incentivize increased infill development, although we note that such tools, in isolation, would not get around restrictive local land use regulations. Additionally, the State could add to the "toolbox" of existing financing tools for infill development and also the financing that is available for critical, infill-supportive infrastructure, which would also likely incentivize an increased share of infill development. Financing tools are likely to be particularly critical in shaping future development patterns in areas of the state where infill is at an economic disadvantage compared to greenfield or more remote development due to market conditions and/or distressed conditions in infill areas. Finally, the State could directly incentivize consumer choice, for example through low-VMT housing rebates or "live where you work" incentive programs. The location of infrastructure, including highways, transit, schools, and major public buildings, can also influence growth patterns.[16] Aligning state infrastructure spending with infill goals, e.g. through performance metrics or other criteria, would be one way to ensure better leverage these investments to further VMT and GHG reduction goals.

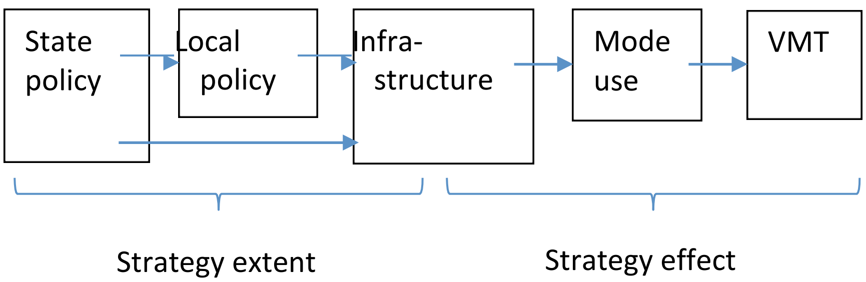
[16] For evidence of the effect of highways on growth patterns, see Funderburg, et al. (2010) and Baum-Snow (2007).

While evidence suggests that state intervention to increase infill development is highly likely to yield reductions in VMT, estimating a more precise degree of impact from state actions – for the purposes of modeling by ARB and others to quantify anticipated VMT reductions from specific strategies – would require further analysis. Table 4 presents an outline of suggested steps for gaining more precision and clarity in this estimation.

3. Transportation Investments

In this section, we separately consider the VMT impacts of three categories of transportation investments: bicycle and pedestrian infrastructure, transit service, and highway capacity. Although the impacts of bicycle infrastructure are distinct from the impacts of pedestrian infrastructure, the methods for projecting their impacts are similar, so we consider them together. The subsection on transit focuses on the impact of expansions in transit service rather than infrastructure per se, given the nature of the research available. We consider only intra-regional transit service, rather than inter-regional service such as high-speed rail, the potential GHG impacts of which have been quantified using an ARB-approved methodology.[17] The subsection on highway capacity differs from the first two in that the available research provides evidence on *increases* in VMT resulting from increases in capacity.

3.1 Bicycle and Pedestrian Infrastructure



Strategy Effect: Impact of Bicycle and Pedestrian Infrastructure on Individual or Household VMT

Investments in bicycle and pedestrian infrastructure have the potential to reduce VMT by encouraging a shift from driving to these active travel modes. A growing body of research shows a strong connection between the extent of bicycle and pedestrian infrastructure and the amount of bicycling and walking in a community. Many of the available studies focus on commute trips rather than active travel for all purposes; some studies do not separate active travel from recreational walking and bicycling. Most studies measure infrastructure investments in terms of miles of facilities or percentage increases in miles of facilities without accounting for the quality of the new facilities or their impact on the connectivity of the bicycle or pedestrian network, though current studies are beginning to provide insights into the effects of facility characteristics and network connectivity, not just extent (e.g. Monsere, et al. 2014).

As summarized in the ARB Research Briefs, differences between the studies do not enable a consensus estimate of the strategy effect, though results from individual studies could be used. A relatively recent study of 24 California cities found that a 1% increase in the percent of street length with bike lanes in a city was associated with an increase of about 0.35% in the share of

[17] https://www.arb.ca.gov/cc/capandtrade/auctionproceeds/hsrinterimqm.pdf

workers commuting by bicycle (Marshall and Garrick, 2010). These results suggest that in a city where 1% of commuters bicycle, a 100% increase (i.e. a doubling) in the percent of streets with bike lanes would increase the bicycle commuter share to 1.35%. For walking, a North Carolina study found that a 1% increase in the portion of the route with sidewalks was associated with a 1.23% increase in the share of walk commuting (Rodriguez and Joo, 2004), though other studies suggest a much more modest effect.

While the literature strongly suggests that bike and pedestrian infrastructure increase biking and walking and therefore decrease VMT, quantifying the precise reductions in VMT is tricky. First, studies suggest that the effects of investments depend on the context, including the adoption of other strategies to promote walking and bicycling, such as educational programs or promotional events (Pucher, et al., 2010). Comprehensive efforts that combine strategic and high-quality infrastructure investments with promotion and education over a period of time have been shown to produce substantial increases in bicycling. In addition, investments in facilities that connect important destinations and contribute to the overall connectivity of the network will have more impact than stand-alone facilities that do not serve important destinations or help to build a larger network. Second, new walking and biking trips do not necessarily replace driving trips; they may replace transit trips, for example, or they may be entirely new trips. The degree to which walking and biking trips substitute for driving trips is difficult to pinpoint, as discussed by Piatokowski, et al. (2015). Third, when these trips do substitute for driving, they may be shorter than the trips they replace, particularly for non-commute trips. For example, an individual may choose to bike to a nearby store rather than driving to a store across town, in which case a measure of the increase in bicycling distance would underestimate the reduction in driving distance. Fourth, reductions in VMT from non-commute trips are also likely to occur. Thus, projected reductions in VMT based on the commute effects are almost certainly lower than the probable reductions. Projecting statewide reductions in VMT resulting from investments in bicycle and pedestrian infrastructure requires assumptions about each of these possibilities, as outlined in Table 5.

Strategy Extent: Impact of State Policy on Bicycle and Pedestrian Infrastructure

Investments in bicycle and pedestrian infrastructure are mostly made at the local level by cities and sometimes counties. State policy can influence such investments through grant programs, for example, Caltrans' Active Transportation Program. The state can (and indeed does) encourage such investments by allowing Metropolitan Planning Organizations to develop their own grant programs using the state and federal funds allocated to the MPO. However, research shows that simply allowing MPOs to spend federal funds on bicycle and pedestrian infrastructure does not guarantee that they will (Handy and McCann, 2011).

Estimating statewide reductions in VMT resulting from State policies and programs that support the expansion of bicycle and pedestrian infrastructure requires an estimate of the increase in bicycle and pedestrian infrastructure over a specified period of time (see Table 5, Step 2). This increase depends on what policies the state adopts, how MPOs and local governments respond to these policies, and how State actions influence the investments that local governments choose to make with their own funds – all very difficult to predict with precision. One approach to estimating the percent increase in bike/ped infrastructure is to estimate the funding available for these investments for the specified period of time, then convert this amount to miles of bike facilities and sidewalks using data on the per mile costs of such facilities. Another approach is to analyze increases in infrastructure for selected cities where good data on the extent of infrastructure at two or more points in time is available. San Francisco, for example, is planning to double its miles of protected bike lanes (from 15 to 30 miles) in the next 15 months.[18] Because bicycle facilities are less ubiquitous than pedestrian facilities, a given length of new facility will represent a larger percentage increase for bicycle infrastructure.

State Policy Considerations for Bike/Ped Infrastructure

The available evidence shows a strong connection between the extent of bicycle and pedestrian infrastructure and the amount of walking and bicycling. Although projecting the VMT impacts of new investments in such infrastructure involves a number of critical assumptions, given limitations in the available evidence, this strategy shows strong potential for reducing VMT, in addition to producing other benefits for the community (see Sallis, et al. 2015 for a discussion of co-benefits).

Research suggests that state actions to increase bicycle and pedestrian infrastructure would be most effective in reducing VMT if implemented in conjunction with promotional and educational programs (Pucher, et al. 2010). In addition, emerging evidence suggests that higher quality infrastructure, such as protected bicycle lanes, are more effective in promoting increases in active travel (e.g. Monsere, et al. 2014), so state actions could prioritize such high-quality infrastructure to ensure maximum VMT reduction per mile of infrastructure. Network connectivity is also now recognized as a critical consideration in prioritizing investments in bicycle and pedestrian infrastructure (Mekuria, et al. 2012), so state actions that prioritize connectivity improvements could again help to ensure the highest VMT reductions per mile of infrastructure.

State policy currently encourages such investments in bicycle and pedestrian infrastructure through grant programs and by giving MPOs flexibility in how they spend their state and federal funds. Stronger state measures could require MPOs to spend a certain share of state funding on these modes or set performance standards for walking and bicycling that MPOs must meet in order to receive funding. Additionally, the State could allocate a greater portion of state transportation funds to direct investments in pedestrian and bicycle infrastructure. Any of these measures can help ensure maximum VMT reduction per mile created by incorporating the considerations in the paragraph above into guidelines for the allocation of funds.

[18] https://www.sfmta.com/about-sfmta/blog/new-generation-bikeways-coming-san-francisco

While evidence suggests that state intervention to increase bicycle and pedestrian infrastructure is highly likely to yield reductions in VMT, estimating a more precise degree of impact from state actions – for the purposes of modeling by ARB and others to quantify anticipated VMT reductions from specific strategies – would require further analysis. Table 5 presents an outline of suggested steps for gaining more precision and clarity in this estimation.

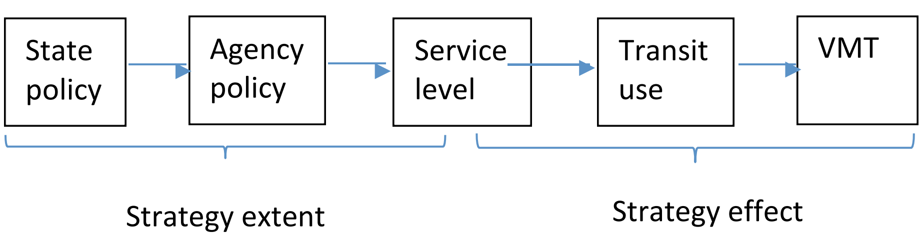
Table 5. Suggested Steps for Calculating VMT Impacts of Bicycle and Pedestrian Infrastructure Investments

Step	**Assumptions or Data Needed**	**Validity of Assumption (Scale: 1 = poor, 5 = excellent)**	**Future research tasks to strengthen assumptions and data**
1. Measure existing bicycle/pedestrian infrastructure	Most common measure is percent of street length with bike/ped facilities	Validity = 3 (fair) Most common measure does not account for quality of facilities or the connectivity of the network.	Develop statewide GIS database of bike/ped facilities, including characteristics of facilities. Develop measures of network connectivity.
2. Measure *changes in bicycle/pedestrian infrastructure* as percentage of current infrastructure	Estimate additional bike or ped infrastructure that could be constructed given funding available, for state or by region.	Validity = 3 (fair) Costs of infrastructure vary by facility type and context.	
3. Use an elasticity of % bike/ped commuting with respect to bike/ped infrastructure to calculate *percentage increase in %bike/ped commute trips*	Use bike or ped elasticity from ARB bicycle or pedestrian infrastructure brief.	Validity = 3 (fair) Bike/ped elasticities may vary by context. Available elasticities account only for bike/ped commuting, not bike/ped travel for other purposes.	Conduct studies of the impacts of bike/ped infrastructure investments that measure changes in all bicycling or walking trips, by trip purpose.
4. Apply predicted percentage change in %bike/ped commute trips to a base-year measure of annual statewide or regional bike/ped commute trips to estimate *increase in total annual bike/ped commute trips*	Use estimate of annual statewide bike/ped commute trips or estimates by region.	Validity = 4 (good) The CHTS has data on bike/ped commute trips statewide and by region. Bike/ped trips may be underreported. (Note that American Community Survey data reports only usual commute mode.)	Improve survey design to better capture bike/ped trips by purpose.

Table 5. Suggested Steps for Calculating VMT Impacts of Bicycle and Pedestrian Infrastructure Investments (Continued)

Step	Assumptions or Data Needed	Validity of Assumption (Scale: 1 = poor, 5 = excellent)	Future research tasks to strengthen assumptions and data
5. Adjust number of trips to reflect switching from modes other than driving to estimate *reduction in total annual driving commute trips*	Apply driving commute mode share for state or by region.	Validity = 2 (weak) Propensity to shift to bike/ped commuting may vary by current mode and by context.	Conduct studies of the impacts of bike/ped infrastructure investments that measure shifts between modes. Conduct such studies in different contexts.
6. Convert reduction in total annual driving commute trips to *reduction in total annual commute VMT*	Use estimate of average commute distance for bike/ped commuters statewide or by region.	Validity = 3 (fair) The CHTS has data on average commute distance for bike/ped commuters statewide and by region. Driving commute trips eliminated by new bike/ped trips may be longer (or shorter) than current bike/ped commute distances.	Conduct studies of the impacts of bike/ped infrastructure investments that measure commute distance for new bike/ped commuters.

3.2 Transit Investments



Strategy Effect: Impact of Transit Investments on Individual or Household VMT

Investments in transit service have the potential to reduce VMT by encouraging a shift from driving to transit. Many different types of investments are possible, including improved access to bus stops and rail stations, coordinated schedules and transfers between systems, real-time information about arrivals and departures, and electronic farecards. As summarized in the ARB Transit Service research brief, however, most research focuses on the effects of changes in fares, changes in service frequency (or changes in headways), or changes in miles of service. Most studies examine the effects of these changes for bus systems, though some report effects for rail systems. Outcomes are measured in terms of changes in transit ridership, i.e. the number of transit trips made for the specified period of time.

According to the ARB research brief, the available research shows that a 1 percent increase in service frequency will lead to a ridership increase of approximately 0.5 percent and that a 1 percent increase in service hours or miles could lead to a higher increase of around 0.7 percent. Effect sizes are likely to be higher in cases where the investments target “choice” riders who are not dependent on transit, higher-income riders, off-peak and non-commute trips, and small cities and suburban areas. These findings are applicable to metropolitan areas but not necessarily to rural areas where transit service is sparse.

As with bicycle and pedestrian investments, although transit investments are likely to reduce VMT, quantifying the effects of transit investments on VMT is not straightforward. First, studies suggest that the effects of investments depend on the context, as noted above. Second, not all new transit trips replace driving trips; they may instead replace bicycling or riding in a carpool, or they may be entirely new trips that would not otherwise have been made. Third, new transit trips may be shorter (or longer) in length than any driving trips they replace. For example, an individual may choose to take the bus to the nearest store rather than driving to a store across town, in which case a measure of the increase in transit distance would underestimate the reduction in driving distance. Projecting statewide reductions in VMT resulting from investments in transit service requires assumptions about each of these possibilities, as outlined in Table 6.

A recent study of the opening of the Expo Line in Los Angeles provides some of the most direct evidence available of the impact of transit investments on VMT (Spears, et al. 2016). This study, which measured VMT for households living near the new light-rail line before and after the opening of the line, found that households living within 1 mile of a new Expo station drove almost 11 miles less per day because of the new line 18 months after its opening. The authors conclude that large investments in light rail, coupled with supportive land use policies, have “the potential to help achieve climate policy goals.”

Strategy Extent: Impact of State Policy on Transit Investments

Because much of the funding for intra-regional transit flows directly from the US DOT to transit agencies, the state role in promoting transit investments is more limited than it is for other modes. In addition, transit improvements are increasingly funded through county and regional sales tax measures, such as the upcoming ballot measures in Sacramento, the Bay Area and Los Angeles. The state provides transit funding through State Transit Assistance[19], bond measures such as Prop 1B[20], and more recently, through the California Climate Investments Fund (cap and trade proceeds).

[19] http://www.sco.ca.gov/Files-ARD-Payments/Transit/statetransitassistanceestimate_1617_january16.pdf
[20] http://www.dot.ca.gov/hq/transprog/ibond.htm

Estimating statewide reductions in VMT resulting from improvements in transit service requires an estimate of the increase in transit service over a specified period of time (see Table 6, Step 2). This increase depends on what policies the state adopts, how transit agencies respond to these policies, and the investments that transit agencies choose to make with their own funds – all very difficult to predict with precision. One approach to estimating the percent increase in transit service is to estimate the funding available for service improvement for the specified period of time, then convert this amount to hours or miles of service using data on the per mile costs of such service. Another approach would be to compile proposed transit investments in the Regional Transportation Plans for the Metropolitan Planning Organizations in the state and assume this level or a proportionately higher level (to reflect new state policy) of investment in transit service.

State Policy Considerations for Transit Investments

The available evidence shows a strong connection between the extent of transit service and transit ridership. Although projecting the VMT impacts of new investments in transit service involves a number of critical assumptions, given limitations in the available evidence, this strategy shows strong potential for reducing VMT.

Service expansions are likely to have more impact when combined with other strategies such as improved access to bus stops and rail stations, coordinated schedules and transfers between systems, real-time information about arrivals and departures, and electronic farecards. The impacts of transit investments on VMT are likely to be higher in cases where the investments target "choice" riders, higher-income riders, off-peak and non-commute trips, and small cities and suburban areas. The State can increase the VMT-reduction impact of state actions to increase transit ridership by considering these conditions when, for example, developing guidelines for funding allocations, along with other considerations that achieve other policy goals, e.g. prioritizing investments in disadvantaged and low-income communities.

Although the bulk of transit funding comes from federal and local sources, the State does provide transit funding to regional and local transit agencies through a number of different programs. The state could ensure larger reductions in VMT by targeting this funding to areas and investments that are likely to have larger impacts. The State could also consider programs that directly encourage transit use, including tax breaks for employer-provided transit passes modeled on federal policy.[21] State policies that promote infill development around transit stations can also help to increase transit use (see section on Infill Development). Efforts to coordinate services among regional and local agencies could prove valuable as well.

While evidence suggests that state intervention to improve transit service is highly likely to yield reductions in VMT, estimating a more precise degree of impact from state actions – for

[21] http://www.nctr.usf.edu/programs/clearinghouse/commutebenefits/

the purposes of modeling by ARB and others to quantify anticipated VMT reductions from specific strategies – would require further analysis. Table 6 presents an outline of suggested steps for gaining more precision and clarity in this estimation.

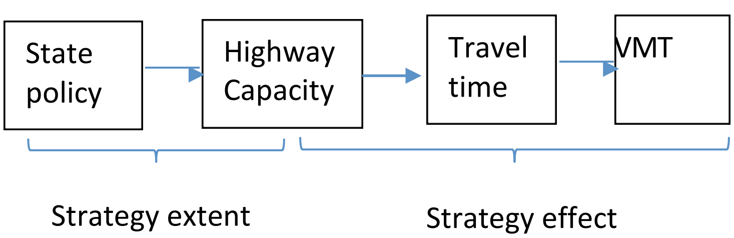
Table 6. Suggested Steps for Calculating VMT Impacts of Transit Investments

Step	Assumptions or Data Needed	Validity of Assumption (Scale: 1 = poor, 5 = excellent)	Future research tasks to strengthen assumptions and data
1. Measure current transit service in metro areas	Most common measures is service hours or miles.	Validity = 3 (fair) Measure does not account for quality of service or connectivity of the transit network.	Extract statewide data on transit service from National Transit Map and add data as needed. Develop measures of network connectivity.
2. Measure *increases in transit service* as percentage of current service by metro area	Compile planned increases in transit service from RTPs and assume proportionate increase based on proportionate increase in funding	Validity = 4 (good) Costs of expansion vary by service type and context.	Develop a GIS database of funded transit service increases
3. Use an elasticity of ridership with respect to transit service to calculate *percentage increases in transit ridership* by metro area	Use transit ridership elasticity from ARB transit brief	Validity = 3 (fair) Transit ridership elasticities may vary by type of improvement and context.	Conduct studies of the impacts of transit improvements of different types and in different contexts.
4. Apply predicted percentage change in transit ridership to a base-year measure of annual transit trips by metro area to estimate *increase in total annual transit trips* by metro area	Use estimate of transit trips by region	Validity = 5 (excellent) Transit agencies report annual ridership.	

Table 6. Suggested Steps for Calculating VMT Impacts of Transit Investments (Continued)

Step	Assumptions or Data Needed	Validity of Assumption (Scale: 1 = poor, 5 = excellent)	Future research tasks to strengthen assumptions and data
5. Adjust increase in total annual transit trips to reflect switching from modes other than driving to estimate *reduction in annual driving trips* by metro area	Apply driving mode share by metro area.	Validity = 2 (weak) Propensity to shift to transit may vary by current mode and by context.	Conduct studies of the impacts of transit improvements that measure shifts between modes.
6. Convert change in total annual driving trips to *change in total annual VMT* by metro area	Use estimate of average trip distance for transit riders by metro area.	Validity = 3 (fair) The CHTS has data on average distance for transit trips by metro area. Driving trips eliminated by new transit trips may be longer or shorter than current transit trip distances.	Conduct studies of the impacts of transit improvements that measure trip distance for new transit trips.

3.3 Highway Capacity



Strategy Effect: Impact of Highway Capacity on Aggregate VMT

Increased highway capacity is sometimes proposed as a strategy for reducing GHG emissions, following the logic that increased capacity will reduce congestion, smooth traffic flow, and thereby reduce GHG emissions through improved efficiency of vehicle operation. A strong body of evidence, however, supports the conclusion that increases in highway capacity do not measurably reduce congestion in the long-run. This phenomenon is referred to as "induced travel" or "induced traffic": the increase in capacity in effect reduces the (time) price of driving, and when the price goes down, consumption goes up.

The most recent and arguably most rigorous study shows an elasticity of around 1 after 10 years (Duranton and Turner, 2011). In other words, a 1% increase in highway lane miles leads to a 1% increase in VMT. Conversely, studies show that reductions in highway capacity, in the few places they have occurred, have not resulted in an increase in congestion, suggesting that VMT either disperses widely or decreases overall, though these effects have not been quantified. Estimating increases in VMT resulting from increases in highway capacity would be relatively straightforward (Table 7).

It is important to note that transportation systems management (TSM) strategies, such as eco-driving programs, incidence-clearance programs, roundabouts, and various other systems operations approaches[22] also have the potential to increase the effective capacity of the highway system. To the degree that they reduce travel times, they may induce additional vehicle travel that could offset whatever improvements in fuel efficiency or reductions in GHG emissions they produce. The VMT-inducing potential of these strategies has not been rigorously assessed.

Strategy Extent: Impact of State Policy on Highway Capacity

Over nearly a century, the State has built a highway system that now totals nearly 25,000 lane-miles of Interstates, freeways, and expressways.[23] In 2014 alone, the California Transportation Commission programmed $2.2 billion in projects for the State's highway system for a two-year period.[24] The Regional Transportation Plans adopted by the MPOs together with the State Transportation Plan outline continued expansions to the highway system, drawing on federal, state, and local funding sources, despite a growing share of the available funding going towards maintenance of the existing system. The projects listed in these plans could be compiled to project the percentage increase in highway capacity over a specified period. An important caveat is that proposed projects are often delayed, sometimes by decades, as priorities change or because of legal challenges to such projects, usually as a part of the environmental review process.

State Policy Considerations for Highway Capacity

As the owner-operator of the highway system, the State has direct control over projects that expand or reduce its capacity. Although county sales tax measures now account for a significant share of highway spending in the State, Caltrans and the California Transportation

[22] See the ARB Research Briefs on EcoDriving, Traffic Incidence Clearance, Roundabouts, and Traffic Operations, available at: https://arb.ca.gov/cc/sb375/policies/policies.htm
[23] Highway Statistics 2014. Table hm60. Available: https://www.fhwa.dot.gov/policyinformation/statistics/2014/
[24] http://www.catc.ca.gov/programs/STIP/2016_STIP/Rev_Fund_Estimate_Jan_16.pdf

Commission must approve these projects. Under current practices, the VMT-inducing potential of these projects is not generally accounted for in the decision-making process. Such analyses could very well show that state investments in highway capacity are at odds with state goals for reducing GHG emissions.

The State could use the California Transportation Plan, or another platform, to establish new policies that limit capacity expansion, e.g. through performance criteria for state funding that take VMT increases into account. The current plan continues to focus on capacity expansion as important for addressing congestion, though it acknowledges that such investments alone will not solve the congestion problem.[25] A state-level "fix-it-first" policy would ensure that maintenance needs are met before funding is approved for projects that expand capacity. New guidelines on analyzing the environmental impacts of proposed highway projects could ensure that potential VMT increases are adequately assessed.[26]

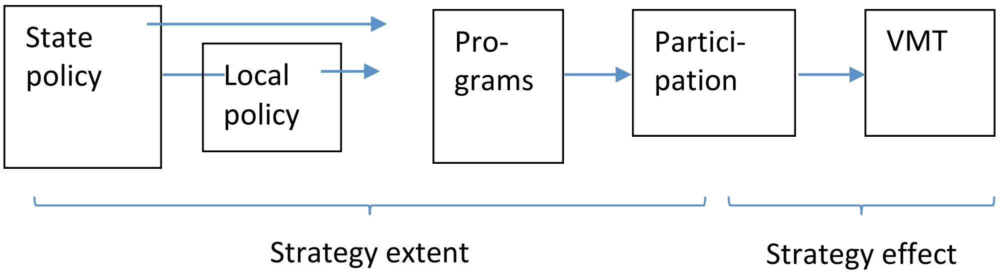
While evidence suggests that state intervention to increase highway capacity is highly likely to yield increases in VMT, estimating a more precise degree of impact from state actions – for the purposes of modeling by ARB and others to quantify anticipated VMT reductions from specific strategies – would require further analysis. Table 7 presents an outline of suggested steps for gaining more precision and clarity in this estimation

[25] http://www.dot.ca.gov/hq/tpp/californiatransportationplan2040/index.shtml
[26] http://www.dot.ca.gov/ser/cumulative_guidance/ceqa_guidelines.htm

Table 7. Suggested Steps for Calculating VMT Impacts of Highway Capacity Expansion

Step	**Assumptions or Data Needed**	**Validity of Assumption (Scale: 1 = poor, 5 = excellent)**	**Future research tasks to strengthen assumptions and data**
1. Measure current highway lane miles statewide	Caltrans data	Validity = 5 (excellent)	
2. Measure *increases highway capacity* as percentage of current capacity statewide	Compile planned highway capacity expansion from state and MPO plans	Validity = 4 (good) Timing of future highway projects beyond those currently programmed in a Transportation Improvement Program is uncertain. Proposed projects can be added or dropped when plans are updated.	Develop GIS database of existing highways, funded highway expansion projects, and proposed but unfunded highway expansion projects
3. Use an elasticity of VMT with respect to highway capacity to calculate *percentage increase in VMT*	Use capacity elasticity from ARB capacity brief	Validity = 4 (good) Evidence is consistent	
4. Apply predicted percentage increase in VMT to a base-year measure of annual statewide VMT to estimate *increase in total annual VMT*	Use VMT measure from Caltrans	Validity = 5 (excellent)	

4. Transportation Demand Management Programs



Transportation demand management programs encompass a variety of strategies, including employer-based trip reduction (EBTR) programs, telecommuting programs, and voluntary travel behavior change programs. Car-sharing services might also play a role in managing demand. While the literature provides strong evidence on the effects of participation in these programs on travel behavior, it provides limited insights into factors affecting the extent to which individuals choose to participate in these programs.

4.1 Employer-Based Trip Reduction Programs

Strategy Effect: Impact of EBTR Programs on Individual or Household VMT

Employer-based trip reduction programs, also known as commute-trip reduction programs, use various approaches to reduce single-occupant car travel to work. Employers may provide services that promote carpooling, such as carpool matching services, preferential parking for carpoolers, subsidized vanpools, or guaranteed rides home for carpoolers. Some programs include financial incentives for participants. Employers sometimes provide worksite facilities for employees who commute by active travel modes. Telecommuting programs and alternative work schedules are often offered as well.

Available studies, as summarized in the ARB research brief, suggest that commute VMT declines by 4% to 6% on average for employees at worksites participating in EBTR programs, including employees who switch from drive-alone to other modes and those who don't. Reductions are likely to be higher when programs offer a broad array of assistance and incentives and at sites with high levels of transit access.

Strategy Extent: Impact of State Policies on EBTR Programs

EBTR programs are implemented voluntarily or as a requirement of local, regional, or state policy. For example, Southern California's Regulation XV, implemented in 1988, required employers with work sites of more than 100 employees to develop employee trip reduction plans. In 1995, State legislation prohibited air districts or other public agencies from mandating employer trip reduction programs unless such mandates are required by federal law. But the State allowed the San Joaquin Valley Air District to adopt a commute-trip reduction program in 2009, and the Bay Area Air Quality Management District adopted a program in 2013. Several Silicon Valley cities have capped single-occupancy auto trips as part of entitlements for new tech company campus expansions.

The extent to which EBTR programs are implemented in the future depends on requirements for such programs as established by state or local policy. Projecting the state-wide VMT reduction potential of such programs requires an assumption about these requirements, for example, that they would apply to all worksites with 100 or more employees. The strategy effect would apply only to commute VMT for employees at the worksites with EBTR programs rather than to all commute VMT. Statewide reductions in VMT could be projected as outlined in Table 8.

Policy Considerations for EBTR Programs

The available evidence shows a strong connection between employer-based trip reduction programs and reductions in commute VMT. The statewide impact on VMT of state policies that require or encourage the adoption of EBTR programs depends on the total number of employees at worksites that adopt such programs. This strategy shows strong potential for reducing VMT depending on the aggressiveness of the state policy.

California could adopt an EBTR program requirement modeled on Washington State's, which requires employers with 100 or more employees in 9 of 39 counties to adopt trip-reduction programs. Such programs are traditionally implemented in metro areas with high levels of congestion, but programs like vanpooling and telecommuting could work in rural areas with long commute distances.

While evidence suggests that state intervention to increase employer-based trip reduction programs is highly likely to yield reductions in VMT, estimating a more precise degree of impact from state actions – for the purposes of modeling by ARB and others to quantify anticipated VMT reductions from specific strategies – would require further analysis. Table 8 presents an outline of suggested steps for gaining more precision and clarity in this estimation.

Table 8. Suggested Steps for Projecting VMT Impacts of Employer-Based Trip Reduction Programs

Step	Assumptions or Data Needed	Validity of Assumption (Scale: 1 = poor, 5 = excellent)	Future research tasks to strengthen assumptions and data
1. Use effect size for work sites to estimate *percentage decrease in commute VMT for participating worksites*	Use effect size from ARB EBTR brief	Validity = 3 (fair) Elasticities will vary by program and context	Conduct studies of the impacts of EBTR programs of different types and contexts.
2. Estimate *the number of employees at worksites of the size specified in the EBTR policy* by metro area	Data is collected by CA Franchise Tax Board	Validity = 5 (excellent)	
3. Use the average commute distance by metro area to estimate *the annual commute VMT for employees at worksites required to adopt EBTR programs* by metro area	Use commute VMT estimates from MPOs and/or Caltrans	Validity = 4 (good) American Community Survey and CHTS provide data on commute VMT	
4. Apply predicted percentage decrease in commute VMT to estimated annual commute VMT for EBTR worksites to estimate *decrease in total annual commute VMT* by metro area	Calculation		

4.2 Telecommuting Programs

Strategy Effect: Impact of Telecommuting Programs on Individual VMT

Telecommuting is the practice of working from home by employees who have a regular work place. Telecommuting may be encouraged as a part of an employer-based trip reduction program (see Section 4.1) or as a stand-alone program. The available research shows strong evidence that telecommuting reduces VMT. As summarized in the ARB Telecommuting research brief, reductions in commute VMT may be as high as 90% on telecommuting days, and personal VMT may decline by roughly 55 to 75% on telecommuting days. Annual VMT reductions for telecommuters depend on how frequently these workers telecommute. Available studies show that telecommuters average 1.2 to 2.5 days per week.

It is important to note that most of the research on the VMT impacts of telecommuting was conducted in the 1990s. With the advent of the Internet, wireless services, and smart phones, today's patterns of telecommuting may be quite different than in the past, and the impacts on driving may be more or less than previously. Anecdotally, it appears that work is increasingly done in places other than the office or home, the VMT implications of which are uncertain.

Strategy Extent: Impact of State Policy on Telecommuting Programs

State and local requirements for employer-based trip reduction programs may encourage the adoption of telecommuting programs. The State might also encourage employers to adopt telecommuting programs through tax incentives and other policies.

Projections from the 1990s as to the share of workers who would be telecommuting by now have not panned out, though telecommuting levels are not insignificant. Measuring the extent of telecommuting is challenging, given increasing flexibility in work sites and work hours. Statewide reductions in VMT could be projected as outlined in Table 9.

Policy Considerations for Telecommuting Programs

The available evidence shows a strong connection between telecommuting programs and reductions in VMT. The statewide impact on VMT of state policies that require or encourage the adoption of telecommuting programs depends on the total number of employees who choose to telecommute and how frequently they telecommute. This strategy shows strong potential for reducing VMT depending on employee demand for telecommuting.

California could encourage telecommuting by adopting a requirement for employer-based trip reduction programs that include a telecommuting program (see Section 4.1). Such programs are traditionally implemented in metro areas with high levels of congestion, but telecommuting programs could work in rural areas with long commute distances.

While evidence suggests that state intervention to increase telecommuting programs is highly likely to yield reductions in VMT, estimating a more precise degree of impact from state actions – for the purposes of modeling by ARB and others to quantify anticipated VMT reductions from specific strategies – would require further analysis. Table 9 presents an outline of suggested steps for gaining more precision and clarity in this estimation.

Table 9. Suggested Steps for Projecting VMT Impacts of Employer-Based Trip Reduction Programs

Step	Assumptions or Data Needed	Validity of Assumption (Scale: 1 = poor, 5 = excellent)	Future research tasks to strengthen assumptions and data
1. Use effect size to estimate *percentage decrease in personal VMT on telecommuting days*	Use effect size from ARB Telecommuting brief	Validity = 3 (fair) Available research is dated, and effect size may now be different	Conduct new studies of telecommuting patterns and impacts
2. Estimate the average number of telecommuting days per week	Use average telecommuting days from ARB Telecommuting brief	Validity = 3 (fair) Available research is dated, and telecommuting frequency may now be different	Conduct new studies of telecommuting patterns and impacts
3. Use the average daily VMT for workers by metro area to estimate *the annual commute VMT for employees who telecommute* by metro area	Use VMT estimates from MPOs and/or Caltrans	Validity = 4 (fair) American Community Survey and CHTS provide data on commute VMT. Telecommuters may have longer commuters than the regional average	Conduct new studies of telecommuting patterns and impacts
4. Apply predicted percentage decrease in daily VMT and average number of telecommuting days to estimate *decrease in total annual VMT for average telecommuter* by metro area	Calculation		
5. Multiply estimated decrease in total annual VMT for telecommuters by estimated number of telecommuters by metro area to get *decrease in total annual VMT* by metro area	Use telecommuter estimates from MPOs and/or Caltrans	Validity = 4 (fair) American Community Survey and CHTS provide data on share of workers telecommuting usually or on any given day, respectively	Develop improved survey questions to measure extent of telecommuting in travel surveys

Conclusions

The available evidence shows that the strategies considered in this paper are likely to reduce VMT if promoted by state policy. The connection between state policy and VMT reduction is more direct for some strategies than others (see Table 10), but the available evidence in all cases points to VMT reductions, even if projections of the magnitude of the statewide effects depend on a number of assumptions. The framework we have outlined for generating statewide projections of VMT reductions for these strategies helps to illuminate the sequence of causal events that would produce VMT reductions and highlights important gaps in knowledge that increase the uncertainty of the projections. Despite uncertainties, the evidence justifies state action on these strategies.

Most of the strategies discussed here are complementary: VMT reductions are likely to be greater if strategies are adopted in combination. For example, infill development coupled with investments in transit service and bicycle and pedestrian infrastructure will have more of an impact than infill development or transportation investments on their own. Pricing strategies will have more impact on VMT (with less impact on household budgets) if good alternatives to driving are available. The one exception to this complementarity rule is highway capacity: new highway capacity (whether from construction of additional lanes or implementation of transportation systems management strategies) is likely to increase VMT through the "induced travel" effect and will at least partly offset reductions in VMT achieved through other strategies.

The timeframe of the strategies is another important consideration. Some pricing strategies can be implemented quickly, if the State has the political will to do so, with direct impacts on the travel choices of Californians. Transportation investments may be a longer term proposition, requiring a series of investments over many years before transit or bicycle networks are extensive enough to attract substantial numbers of drivers. Infill development is also a longer term proposition, as new development represents a small increment of all development in any one year. But these longer term strategies are essential for providing and improving alternatives to driving that enable more painless VMT reductions; they also produce many other benefits for communities as discussed in the ARB research briefs (see also Sallis, et al. 2015).

We have also outlined the need for improved data and additional studies to reduce the uncertainty in projections of the statewide reductions in VMT that state policy might produce. Investments in data and research are well justified by the significance of the policies under consideration and the seriousness of the problem they would address. However, the State does not need to wait for new data or research to act. In fact, the State is already acting through numerous policies that directly and indirectly influence VMT whether that was their purpose or not. The existing evidence is strong enough to point the State in the right direction to achieve the needed reductions in VMT starting now and over the decades to come.

Table 10. Summary of State Policy Options

Strategy Category	State Policy to VMT Link	Effect on Individual VMT	Potential for Statewide Implementation and Adoption – Strategy Extent
Pricing	Most direct	Strong effect Solid evidence	Can be applied state-wide (fuel taxes, VMT fees) and in targeted areas (link pricing, cordon pricing, parking pricing). Most effective where individuals have good alternatives to driving. Strategies have equity implications. Generates revenues that can be invested in transportation system.
Infill Development	Direct and indirect	Moderate effect Solid evidence	Most applicable in metro areas. Will affect populations living and working in infill areas. May depend on changes in local land use policy. May require financial incentives. Land use changes and VMT effects accrue over the long term.
Transportation Investments			
Bike/Ped	Direct and indirect	Small effect Moderate evidence	Most applicable in metro areas. Will affect populations living and working where investments are made. May depend on changes in local investments. May require financial incentives. May require package of strategies. Many co-benefits.
Transit	Direct and indirect	Small effect Moderate evidence	Most applicable in metro areas. Will affect populations living and working where investments are made. May depend on changes in transit agency action. May require financial incentives. May require package of strategies. Many co-benefits.
Highways	Direct	Strong *induced VMT* effect Solid evidence	New capacity that reduces travel times leads to VMT growth. Effect is greatest in congested areas. Operational improvements that reduce travel times can also induce VMT.
Transportation Demand Management	More indirect	Moderate effect Solid evidence	Most applicable in metro areas. Generally implemented by large employers in response to state or local requirements or financial incentives. Some applications appropriate for rural areas.

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Appendix: Linking Scenario Planning Models of Infill Development to Fine-Grained Data on the Effect of Infill Strategies

Table A1 shows an example calculation of the effect size of moving from the third to fourth quintile of regional job access or from the fourth to fifth quintile of regional job access in the Los Angeles region, as shown in Figure 1 in the text. The data in Table 2 show mid-points of the gravity variable quintile from the ranges that are reported in Boarnet et al. (2011).

Following across columns in Table 2, moves from the mid-point of the third quintile of job access to the fourth quintile increase the gravity job access variable by 38.72 percent, based on the values reported in Boarnet et al. (2010). Using an elasticity range of -0.13 to -0.25 from the ARB briefs, the resulting change in household VMT is 38.72 percent multiplied by -0.13 or -0.25, or a reduction of from 5.03 to 9.68 percent in household vehicle travel. Similarly, moving from the fourth quintile of job access (e.g. in Lakewood, per Table XX) to the top quintile (e.g. near downtown) is a 102.65 percent increase in the job access measure, which when multiplied by the low and high values for the elasticity imply a reduction in household VMT ranging from 13.34 to 25.66 percent. These estimates bound the 18 percent VMT reduction that we obtained in the body of the report from distance measures rather than gravity measures, suggesting that using distance to the metropolitan area downtown can be a good approximation for more complex measures of job access.

Table A1: Example Calculation of Effect of Moves Across Job Access Quintiles on Daily Household VMT

						from ARB regional accessibility brief	
			elasticity from ARB brief			**% change VMT**	
Access quintile (from Boarnet et al. 2010)	mid-point of gravity variable range	% change mid-point access across adjacent quintiles	Low estimate	High estimate	HH VMT miles/day (from Boarnet et al. 2010)	Low estimate	High estimate
5th	524.75	102.65	-0.13	-0.25	47.81	-13.34%	-25.66%
4th	258.94	38.72	-0.13	-0.25	47.81	-5.03%	-9.68%
3rd	186.67		-0.13	-0.25	47.81		

Sources: Calculated from data in Boarnet et al. (2011) and ARB regional accessibility policy brief (https://arb.ca.gov/cc/sb375/policies/regaccess/regional_accessibility_brief120313.pdf.)

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Equity in Congestion-priced Parking

A Study of SFpark, 2011 to 2013

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Abstract

Cities could reduce or eliminate cruising for parking by correctly setting parking meter rates, but would doing so harm lower-income drivers? We examined the question using data on more than 17,000 parked vehicles and their drivers from SFpark, a federally funded market-priced parking experiment in San Francisco. We found that lower-income parkers are more likely to use street parking. Meter rates had small effects on usage. Raising prices did not increase sorting across blocks by income. Controlled analysis yielded mixed and weak evidence that lower-income parkers may be more sensitive to price increases. We discuss policy implications.

Final version: October 2017

1.0 Introduction

In cities around the world, the price of street parking is often too low, leading to parking shortages and cruising for parking (Manville, 2014). Empirical estimates of cruising's prevalence and severity vary, but researchers generally believe the social costs of on-street parking search can be high, as searching results in increased vehicle miles travelled, pollution and greenhouse gas emissions (Shoup, 2011; Inci, 2015).

One solution to this problem is to price on-street parking dynamically, raising rates when demand is higher and lowering rates at times and in places where demand is lower. Spurred by reformers like Shoup (2011), cities from San Francisco to Los Angeles to Seattle are increasingly adopting some form of market-priced parking.

Such demand-based parking charges should make parking more efficient. But are they fair? If fairness dictates that people pay for what they consume, then the answer is surely yes. However, demand-based prices could also fall heavily on low-income people. In this article, we examine this concern empirically.

We know little about how higher street parking prices will affect the disadvantaged, in part because we know little about who actually uses street parking. Street parking sessions are not recorded in travel diaries or Census data, and the few original surveys conducted of street parking have not examined price changes. As a result, evidence about the equity impacts of market-priced parking, or parking pricing generally, is scarce and inconclusive (for example, Clinch and Kelly, 2004; Kelly and Clinch, 2006). Some research suggests that higher-income people are willing to pay more for parking than lower-income people (for example, Anderson *et al*., 2006), but this evidence is unsurprising and only tangentially relevant to fairness concerns.

Our contribution lies in using original data we collected during the SFpark programme, a federally funded pricing experiment that took place between 2011 and 2013 in San Francisco. During SFpark, transportation officials adjusted meter prices based on demand, with the primary goal of increasing vacancy on high-demand blocks, and a corollary goal of increasing occupancy on underused blocks. While transportation experts generally lauded the programme, some critics decried it as elitist and unfair to all but the rich (for example, see James, 2012).

SFpark offers a unique opportunity to examine how price changes influence parking behaviour, because prices changed multiple times in the same places over a short period of time. From 2011 to 2013, we observed more than 17,000 parking sessions on a stratified sample of about fifty blocks within the areas covered by SFpark. We measured socio-economic status using the observed race/ethnicity of the driver and the estimated value of the vehicle. During our final round of data collection in spring and summer of 2013 we also administered an intercept survey, collecting a home zip code and stated trip purpose from more than 1,000 drivers.

Our results shed light on who uses on-street parking, but also illustrate the methodological and conceptual challenges of measuring the impact of price increases on the poor. Our survey suggests that lower-income people are over-represented among street parkers, indicating that rising prices could create an equity problem. We found that changing meter rates did little to change the socioeconomic composition of street parkers. Higher prices did not seem to 'price out' lower-income drivers. The reasons for this seemingly small effect remain unclear, but may relate to the relative inelasticity of demand for street parking among lower-income households, or to the accuracy of our race/ ethnicity and vehicle value estimates. Towards the end of the article we discuss these explanations, along with steps cities can take to minimise the potential burden of higher prices on lower-income drivers.

1.1 Prices and parking consumption: conception and measurement

A demand-based street parking pricing programme changes meter rates upwards and downwards to keep at least one space vacant on crowded blocks, and to encourage higher occupancy on less-popular blocks. Creating vacancies on crowded blocks means raising the price, and a rising price means lower-income parkers could suffer. Lower-income people could be forced to spend more of their income on street parking, to travel more slowly (by switching to transit or walking), to give up some trips, or to park farther away.

The economist's ideal solution to such problems is to redistribute income, not regulate prices. But income redistribution in the United States is often politically difficult, and especially so at the local level (for example, Alesina and Glaeser, 2004; Peterson, 1981). It thus becomes more important to understand if the burden of rising prices lands heavily on the poor.

Three theoretical ideas ground this empirical exercise. First, parking prices are regressive, and like all regressive charges their burden rises as income falls. Second, parking prices are regressive only through the population of people who park. People who park are people who drive, and drivers are in general more affluent than non-drivers. Thus increased parking prices might burden the poorest members of a richer group, rather than the poorest members of society. Third, switching to demand-based pricing may cause some prices to fall — as indeed happened during SFpark, where average meter prices fell eleven cents. If lower-income people tend to park in places where meter rates are likely to fall, or if prices fall within a short walk of where they rise, the equity impacts of higher prices could be blunted — or even positive, if the extra walking cost is valued less than the price reduction.

1.2 Reactions to higher prices, in theory

All else equal, we might expect people to consume less street parking when its price rises, regardless of their ability to pay. The extent to which they do — the elasticity of demand for street parking — depends on multiple factors. One factor is the price and availability of substitutes. How easy is it to switch from on-street parking to off-street parking, to a different mode like transit or walking, or even to a different priced street space nearby? A second factor is the share of the budget that street parking accounts for. A 10 per cent increase in an item that is 1 per cent of the household budget will spur fewer changes than a 10 per cent increase in an item that is 10 per cent of the budget. Both of these factors suggest that for any given price increase, lower-income people will reduce parking consumption more than higher-income people.

A third factor, however, is the extent to which parking is a necessity or a luxury. Precisely because they have less money, lower-income people may be less likely to use paid street parking to begin with, and may only use it when necessary — for example, when they have physical limitations, or are in a particular hurry. Higher-income people, in contrast, might park at meters for a longer time and for less pressing tasks, because the price accounts for a much smaller share of their incomes. When prices rise, all groups might give up some of their discretionary parking, but if lower-income people are parking for discretionary purposes less than higher-income people, they could be less responsive to meter rate increases.

People who consume less street parking when prices rise might adjust in a number of ways. They could forego travel altogether, or walk, bike, or take transit to their destination. Alternatively, they could change the way they use metered parking. They could carpool, splitting the higher meter rate among more people. They could park in the same space at the same time but abbreviate their stay — for example, parking ten minutes instead of twenty. If the hourly rate is lower at other times of day on the same block, and their trip is not time-sensitive, they could park in the same space for the same duration at a different time. They could also find cheaper parking nearby, either off-street or at a nearby block with lower rates.

Drivers could also respond to rate increases by parking without paying. A driver can stay with the vehicle while passengers run errands, and pay only if enforcement officers arrive. Drivers can leave their vehicles and hope they are not caught. Drivers can also acquire permits, such as disabled placards, that allow free parking. These placards can be acquired and used both legally and illegally (Manville and Williams, 2012).

A priori, then, the equity implications of demand-based parking pricing are ambiguous. They depend on whether prices rise more than fall, and particularly if they rise more than fall in spaces where lower-income drivers were parking before prices changed. When prices do rise for lower-income people, the burden they impose will depend on the available alternatives to paying the higher rate, and these alternatives include parking elsewhere, parking at other times, using other modes, choosing not to travel, or choosing not to pay. If drivers choose not to pay, the equity implications would further hinge on whether the non-payment is legal, and how it occurs across different socioeconomic groups.

The empirical challenge, as mentioned above, is that much of this is difficult to measure. Street parking prices rarely change, and the usual data sets relied upon by transportation researchers do not include parking data.

2.0 Data Collection and Analytical Approach[1]

Ideally, when collecting data we would be able to follow people over time, knowing their incomes, and watch where they park and how they react when parking prices rise. A research design of this sort would allow us to measure directly not just the burden of rising prices but also its benefit — whether the utility of lower-income people who paid higher prices outweighed the disutility suffered by people priced away. Knowing both benefit and burden could let us draw conclusions about pricing's impact on welfare.

Such a research design is unfortunately well beyond the scope of this study. Our second-best approach is to observe parking spaces over time rather than follow parkers. Doing so lets us empirically document how parking patterns change over time among different socio-economic groups as prices change. The limitations here are obvious: we must estimate SES,

[1]Parts of this section were excerpted from Chatman and Manville (2014) prior to revising.

we must infer rather than observe displacement, we cannot know what people choose to do when they are displaced, and we can only infer the negative impacts of pricing, not its benefits. Our approach nevertheless represents a large step forward empirically from what has been done previously.

Under the SFpark programme, the San Francisco Municipal Transportation Agency (SFMTA) converted about 25 per cent of San Francisco's roughly 28,800 metered street parking spaces to dynamic pricing.[2] Before the programme, meter rates ranged from $2 to $3.50 per hour, and varied by neighbourhood but not time of day or day of the week. The SFMTA selected eight 'treatment' areas and four control areas for the SFpark programme; installed 'smart' meters that allowed both credit card and remote payment; and placed magnetic sensors that could detect occupancy in the pavement beneath spaces. These sensors and meters relayed information wirelessly to the SFMTA, which used this information to set meter rates that varied by block, by day (weekday versus weekend), and by time of day.

To make price changes, SFMTA broke each day into three 'timebands' — morning (7 or 9 am to noon), midday (noon to 3 pm), and afternoon (3 pm to 6 pm). Any price for any of the three time bands on a block could rise or fall depending on observed occupancy levels. Thus if a block was congested in the morning but largely vacant in the afternoon, the morning rate would rise and the afternoon rate would fall. SFMTA adjusted rates no more than once per month, and in practice usually only every two months. Rates also could not rise more than twenty-five cents per adjustment, nor fall more than fifty cents. Additionally, when the programme began the SFMTA relaxed meter time limits. Spaces that once limited occupancy to a maximum of one or two hours now allowed parking for at least four hours, and in some locations indefinitely.

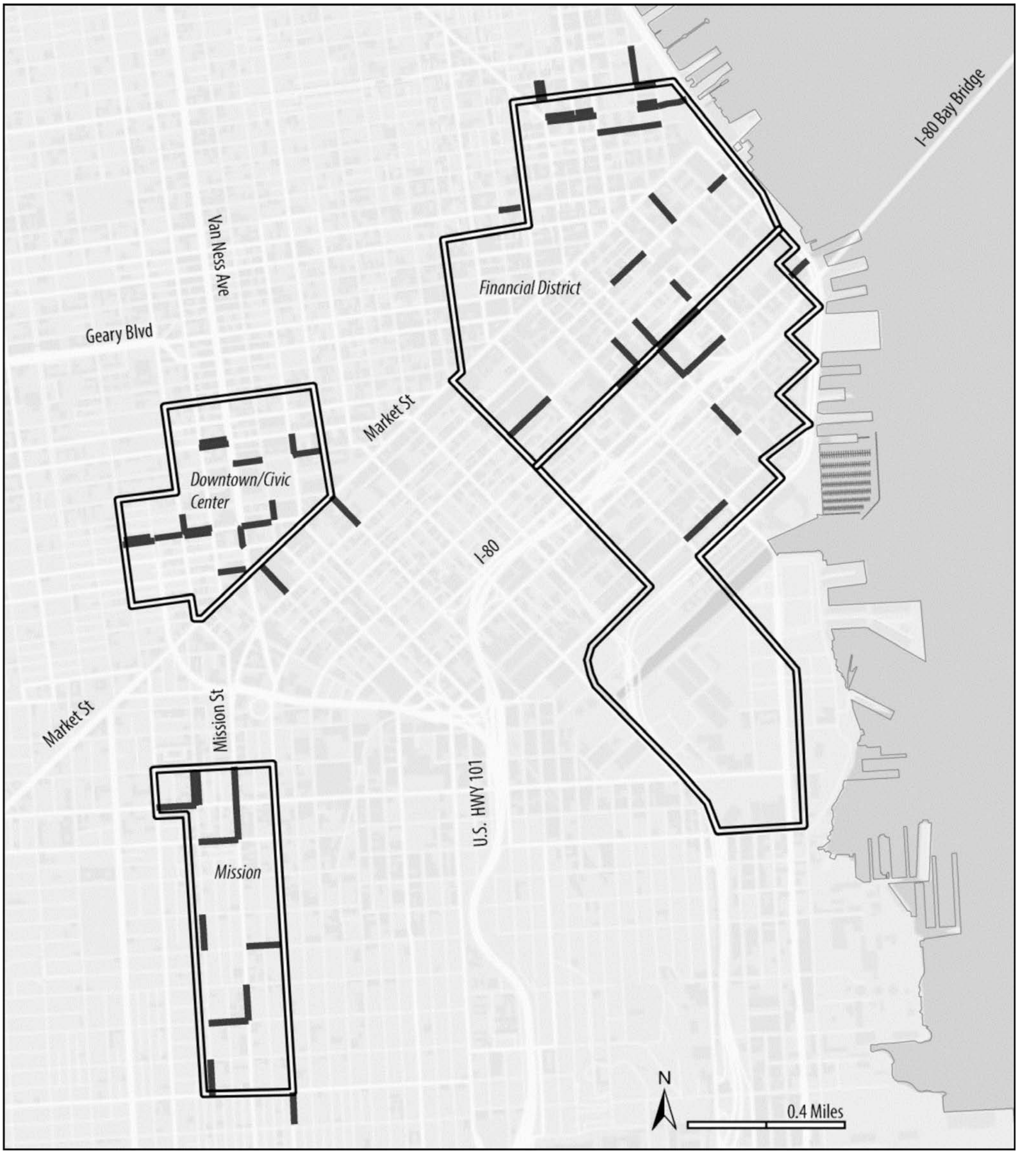
Importantly, the SFpark programme did not change the use of meter revenue. Before, during and after SFpark, the SFMTA used parking revenue to help finance public transportation, and the programme was designed not to substantially influence overall revenue collection. Had the programme changed the amount of revenue or how it was spent, that might change the welfare of lower-income people. Because the amount and purpose of parking spending remained unchanged, however, the primary change faced by low-income travellers was the price of parking itself.

We studied forty-two block faces in four SFpark treatment zones (Mission Street, the Financial District, Civic Centre, and South of Market, or SOMA) and ten 'control' block faces nearby (Figure 1). As with the experimental blocks, the control blocks had smart meters and relaxed parking time limits, but their prices did not change.

We initially chose these fifty-two block faces using random sampling, stratified by the four experimental zones and nearby control blocks. However, it became quickly apparent that random sampling would not provide enough price variation to conduct the study. SFpark's pre-programme occupancy data, available on its web site, showed that many blocks were already within their target occupancy ranges — a fact confirmed later, when prices on these blocks rarely changed. Because our goal was to examine the effect of price changes, and because our budget restricted our sample size, we needed to have prices change, and preferably rise, on a large share of the blocks we observed. We therefore

[2]Source: http://sfpark.org/about-the-project/faq/the-basics.

Figure 1
Map of Blocks Included in Study



Note: Double lines are SFPark boundaries. Thick solid lines are block faces observed at least once during the study period.

introduced an additional level of stratification, and randomly sampled blocks where average occupancy was high enough to trigger changes. For this reason, unlike in SFpark overall, the average meter price across blocks in our sample rose by 16 per cent (forty-six cents), from \$2.89 to \$3.35.

Table 1
Observations by Round

	Round 1	*Round 2*	*Round 3*	*Round 4*	*Total*
Observation period	May 2011	October 2011	May 2012	May – June 2013	
Block faces observed	50	51	48	43	192[1]
Vehicles observed	5,073	5,093	4,245	3,371	17,782

Note: While 192 days of block face observations were carried out, a total of fifty-two blocks were observed, with forty blocks observed both in round 1 and in round 4.

We tried to observe each block face four times between the spring/summer of 2011 and the spring/summer of 2013. Each observation involved paid student surveyors, generally working in pairs and in 3- to 5-hour shifts, recording a full day of parking sessions (typically from 7 or 9 am until 6 pm). On average we surveyed a block four weeks after SFMTA announced a price change, to allow drivers time to adjust. We conducted our first observations in May 2011, after SFMTA had installed smart meters and removed time restrictions, but before it made any price changes. Our second round of observations started in late October 2011, after price changes that occurred in August and in October, and ended in January 2012. Round 3 began in May 2012 after prices changed earlier that month. Round 4 ran from May to June of 2013. We were unable to observe every block four times, because at different times roads were closed for construction or street events; thus the number of blocks observed went down from fifty-one to forty-eight between rounds 2 and 3. Also, in the final round of observations in 2013 we administered an intercept survey, which required additional research staff (more below), reducing the number of blocks further given our limited budget. In total our surveyors observed 17,782 parking sessions, 17,359 by non-professional drivers (for example, not taxis, delivery vehicles, or work trucks). The non-professional observations comprise our sample (Table 1).

We administered our intercept survey during most but not all of our round 4 observation shifts. The survey asked drivers for their trip purpose and home zip code. We intercepted roughly one third of the parkers we observed during this round. When we failed to intercept a driver, it was usually because the vehicle had been parked before the metering period began, or because an extra research assistant was not available to intercept drivers during that shift. Of the drivers we approached, 70 per cent participated, yielding 1,108 respondents.

We used our observations and survey responses to build measures of parking behaviour and socioeconomic status. For parking behaviour, our observers recorded when a vehicle arrived and when it left, which we used to measure parking frequency and duration. The observers also noted whether drivers paid, whether vehicles had disabled or other credentials that allowed them to park for free, and the number of vehicle occupants.

2.1 Collecting data on socioeconomic status

Because we could not directly collect income data, we collected two proxies for socioeconomic status. Our first proxy was the race/ethnicity of the driver. (Race and ethnicity are distinct concepts, but as we explain below, our data collection limitations necessitate the use of this paired phrase.) This variable serves two purposes. First, in San Francisco and

Table 2
Average Income[1] by Race/Ethnicity and Auto Ownership, City of San Francisco, 2011–13 (ACS PUMS 2011–13)

Racial/ethnic group	*Average household income[2]*	*N*	*Share with or without vehicles*	*Share of total (%)*
White, non-Hispanic				
With vehicle(s)	$153,202	3,737	52%	39
Without vehicles	$74,540	1,261	48%	13
Black, non-Hispanic				
With vehicle(s)	$70,559	274	46%	2
Without vehicles	$26,633	212	54%	2
Asian, non-Hispanic				
With vehicle(s)	$109,507	2,018	51%	21
Without vehicles	$43,128	771	49%	8
Hispanic				
With vehicle(s)	$92,117	669	47%	7
Without vehicles	$40,495	300	53%	3
Other[3]				
With vehicle(s)	$113,664	208	48%	2
Without vehicles	$59,711	102	52%	1

Notes:
[1]Household income represents income received in 2011 in 2011 dollars.
[2]Differences in mean household income are statistically significant (at the 1 per cent level) between all race/ethnicity groups by vehicle ownership.
[3]'Other' includes Native American and two or more races.
Source: American Community Survey Public Use Microdata Sample, 2011–13.

its larger metropolitan region, race/ethnicity is highly correlated with household income. Among San Francisco's households with and without vehicles, income differences by race/ethnicity are substantial (Table 2). Among vehicle-owning households, average income for non-Hispanic White households is over $153,000, compared to $110,000 for non-Hispanic Asian households, $92,000 for Hispanic households and $70,000 for non-Hispanic Black households. Note, however, that within-group differences by vehicle ownership are much larger than between-group differences of drivers. Drivers in every group are far richer than non-drivers. The average income of White vehicle-owning households is much higher than that of Black vehicle-owning households, but the average income of Black households owning vehicles is only slightly below the median.

The second reason to examine race/ethnicity is that it is an important metric in its own right. Even controlling for income, Blacks and Hispanics carry more social burdens than other Americans, and these disparate impacts can occur in transportation as in other areas of society. Indeed, the US government orders transportation agencies to consider burdens upon historically disadvantaged racial groups in all programmes that they fund.[3]

[3]See Presidential Executive Order 12898, U.S.DOT Order 5610.2(a), and Title VI of the Civil Rights Act of 1964.

Due to our data collection methods, our race/ethnicity classification differs from that of the U.S. Census. Census respondents self-report race and ethnicity, and the Census allows for both multiple racial categories and a separate tabulation of Hispanic/Latino status (for example, a person can be both Hispanic and Black). Our observers, in contrast, judged the race/ethnicity of each driver based on the following exclusive categories: non-Hispanic White, non-Hispanic Black, non-Hispanic Asian, Hispanic/Latino, or other. In some instances these observations may not match drivers' self-reported race/ethnicity identification, although it is impossible to know how often this occurred. Evidence from the psychology literature suggests that observer judgements generally match the self-reported race/ethnicity of Blacks and Whites, but are less accurate with self-reported Latinos and Asians (Harris, 2002; Herman, 2010). Furthermore, we were unable to observe the driver's race/ethnicity for 448 vehicles that were parked before our observation periods began, leaving 16,911 race/ethnicity observations.

Our second SES proxy was the estimated value of the parked vehicle. While some lower-income households carry inordinate debt on expensive vehicles, and some affluent households drive modest cars, household vehicle values generally rise with income (for example, Q1 Khoeini and Gunstler, 2014; Miller *et al*., 2007; Choo and Moktharian, 2004). Our obser- Q2 vers collected the make and model of each vehicle and recorded its condition. They were unable to collect the year of manufacture because this is not directly observable, and we made a decision not to collect vehicle identification numbers (VINs) because we felt this would be too intrusive. Observers marked the condition 'excellent' if it appeared brand new or had minimal exterior flaws, 'good' if it appeared several years old and had some exterior flaws, and 'poor' if it was much older and/or had numerous exterior flaws. We used this information to estimate each vehicle's selling price, based on the Kelley Blue Book, using a method that accounted for the fact that the year of manufacture was not observable.[4] We first referenced, for each observed make and model, the 2012 value of a used version of a baseline model of that vehicle in 'excellent condition', purchased through a private party seller. (For vehicles no longer in production, we used the 'excellent condition' selling price for the most recent production year.) We then multiplied the selling price by 0.2, 0.5, or 0.8, to generate a value reflecting the vehicle's condition (poor, good, or excellent).[5]

To save time, we excluded any model we saw less than five times. In addition to these deliberately excluded vehicles, our observers sometimes did not legibly record the vehicle's model or condition. The excluded and incomplete vehicle information cases account for 11 per cent of observations. For vehicles with no recorded model, we assigned the average price of all other observed models in that observation round that were in similar condition

[4]Source: Kbb.com.

[5]We used the multipliers to capture not just condition but also the fact that earlier-manufacturing-year vehicles within the same make and model have a lower market value. Because almost all of our analysis using estimated vehicle values is based on categories (tertiles) of vehicle value-low, medium and high-the analysis is more robust than it would be if we were to assume that each estimate of value was precisely correct. By using categories, our classification of vehicle values becomes less sensitive to measurement errors. One way to illustrate this robustness is to examine how different assumptions for the condition multipliers affect how vehicles get categorised into the low, medium, and high values. We compared using three alternative multiplier schemes for vehicle condition and found 95 per cent concordance between all schemes.

and produced by the same manufacturer. For vehicles with no recorded condition, we assigned the average condition of all other observed vehicles of the same make observed in the same round. We also excluded the roughly 2 per cent of observations (423 of 17,782) that were commercial vehicles, leaving 17,359 vehicle-value observations.[6]

3.0 Analysis

Much of our analysis is purely descriptive. Because there is so little data on the universe of on-street parkers, the summary data is itself of intrinsic interest. We also analysed our data using regressions to examine how price changes were associated with changes in parking behaviour by race/ethnicity or by vehicle value.[7] These regressions control for confounding factors such as block-level fixed effects, weather, seasons, day of the week, and nearby employment levels. Finally, we analysed the intercept survey data to explore the potential role of trip distance and trip purpose in affecting price responses by different SES groups.

3.1 Descriptive analysis

We begin our analysis by describing price trends on the sampled blocks; the distribution of observed parkers by race/ethnicity and vehicle value; duration of parking spells, carpooling, and non-payment by race/ethnicity and vehicle value; and heterogeneity across observed block faces over the four observation rounds.

3.1.1. Price trends

In both SFpark overall and within our sample, prices began low and narrowly distributed. In our sample prices ranged from \$2 to \$3.50 per hour. As the programme progressed, the average price rose and the distribution widened. By mid-2013, prices were up 16 per cent on average, and prices ranged from \$0.25 to \$6. The largest reduction was \$2.25 per hour, and the largest increase was \$2.50 per hour (Figure 2).

Prices often rose and fell in close proximity. At the end of the study period in mid-2013, almost every block with relatively high prices was within a few blocks of one with relatively low prices (see Appendix). The exceptions occurred in the Financial District, where almost no blocks were under \$2 per hour. Even here, however, the most expensive blocks (at \$6 per hour) were within a few blocks priced at \$2 per hour.

3.1.2 Observed race/ethnicity

A slight majority of our observed drivers were White (51 per cent) followed by Hispanics (22 per cent), Asians (14 per cent), Blacks (8 per cent), and other/unknown (4 per cent). Comparing these results to data from the American Community Survey (ACS) suggests that both Black and Hispanic drivers were over-represented at meters, at about double their population share (Table 3). Black households with vehicles were about 4 per cent of San Francisco's vehicle owning household population, but 8 per cent of our

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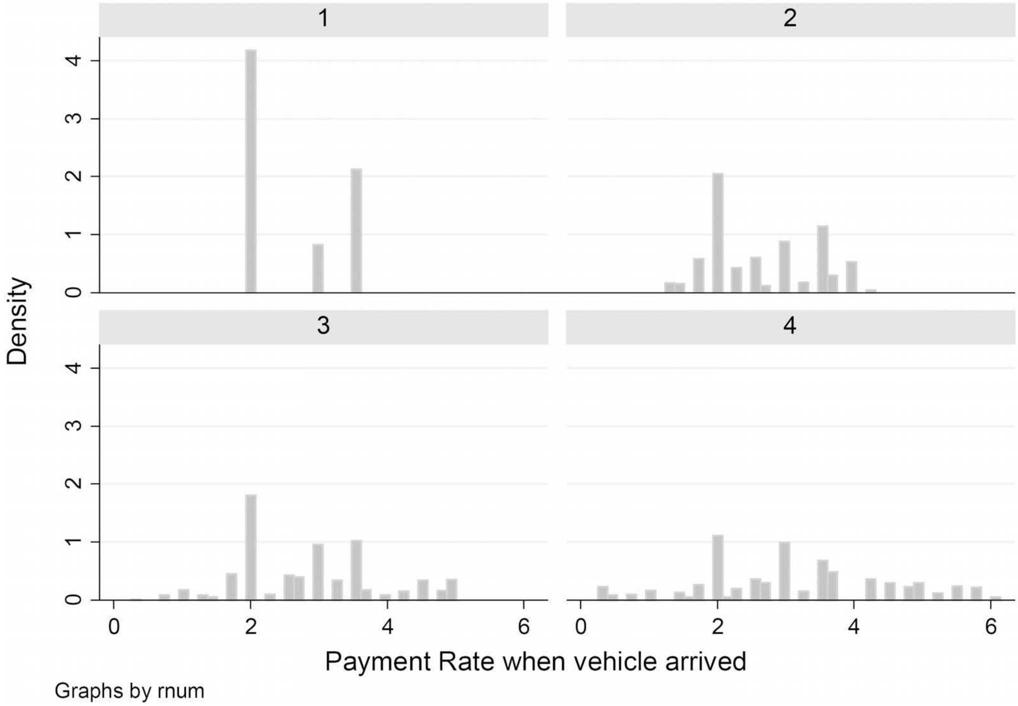
[6]A total of 88 per cent of observed commercial vehicles did not pay the meter, and half stayed ten minutes or less.
[7]Strictly speaking, our SES proxies are estimations of race/ethnicity and estimations of vehicle value. For ease of exposition, here and in in the remainder of the paper we refer to them simply as 'race/ethnicity' and 'vehicle value'.

Figure 2
Price Variation by Round (Spring 2011 to Spring 2013)



Note: For the thirty-six blocks observed in all four rounds.

Table 3
Share and Average Vehicle Value of Parked Vehicles[1] *by Observed Race/Ethnicity Category*

Observed race/ethnicity	*N*	*Share*	*% of households with vehicles in ACS data*[2]	*Average vehicle value*[3]
White	8,650	51%	55	$12,829
Latino	3,783	22%	10	$10,105
Asian	2,421	14%	29	$12,503
Black	1,317	8%	4	$11,307
Other or unknown	740	4%	3	
Total	16,911			

Notes:
[1]Excludes professional vehicles and vehicles parked prior to beginning of observation shifts (n = 871).
[2]American Community Survey, three-year estimates for San Francisco County, using race/ethnicity categories non-Hispanic White, Hispanic/Latino, non-Hispanic Asian, and non-Hispanic Black.
[3]See text for explanation of vehicle value estimates.
Source: Observational survey by authors.

observations. Latino households with vehicles were about 10 per cent of the city's vehicle owning household population, but Latinos drove about 22 per cent of our observed vehicles. Whites were slightly under-represented at the curb, and Asians were highly under-represented, at about half their population share. We found similar results comparing our observations to data from the California Household Travel Survey (2012—13) from respondents making at least one trip to San Francisco on the survey day. We also looked at ACS one-year sample data for 2011, 2012, and 2013 for San Francisco, to determine whether there were any significant changes over the period that might affect our survey data. The population of San Francisco grew about 3 per cent over this time. Growth was very similar across racial/ethnic groups and the racial composition by population of San Francisco changed very little. There were no substantively or statistically significant changes in the shares of the population accounted for by the four racial/ethnic groups used in this study. Over the period, non-Hispanic Whites increased their average income by about $8,400 as compared to an increase of $5,400 for Latinos and just $254 for non-Hispanic Blacks.

3.1.3 Estimated vehicle values

For ease of analysis, and to reflect the error in our vehicle value estimates, we simplified our vehicle value estimates by dividing them into three roughly equal-sized groups, or tertiles: high-, medium-, and low-value vehicles. The low-value tertile includes vehicles valued up $8,200, the middle-value range includes vehicles from $8,201 to $12,900, and the high-value range includes vehicles at $12,900 and above. The high-value tertile unsurprisingly has the largest variance: the category begins at $12,900 and includes a handful of vehicles valued at $250,000. These outliers were rare and have no influence on our analysis, however. The mean and median values in the top tertile were $21,000 and $18,000, and less than 1 per cent of the tertile was valued at over $40,000. Over the course of the four observation rounds, the average vehicle value increased modestly (8 per cent), from about $11,400 to about $12,300. The increase in vehicle values reflects mainly a somewhat better condition of vehicles observed in each successive round, as well as a slightly higher share of higher-value makes and models.

3.1.4 Income proxies based on race/ethnicity interacted with vehicle value

Race/ethnicity and vehicle value are only weakly correlated in our data. Whites have higher incomes than other racial/ethnic groups, and Whites drive more valuable cars on average, but the inter-group differences are not stark (Table 3).[8] Indeed, for all racial/ethnic groups, the mean vehicle value was in the middle tertile. Whites were slightly under-represented in the low-value tertile (43 per cent of these vehicles are driven by whites, compared to 49 per cent of all vehicles) and slightly over-represented in the highest (55 per cent). Similarly, the mean vehicle value for Hispanic drivers was just over $10,000, which is less than the mean value for whites, but twice the mean for the lowest tertile of vehicle value.

[8]Average vehicle value is higher for Black drivers than for Latinos, even though San Francisco's Black vehicle-owning households have substantially lower household income than its vehicle-owning Latinos, as shown in Table 2. But these higher vehicle values are consistent with other evidence showing that at any given level of income, Black households tend to spend more on vehicles than other racial/ethnic groups (Charles *et al*., 2008). Q3

This weak correlation could suggest that our sample is not very income-diverse, or that a lot of income heterogeneity lies within the middle tertile. In either case it leaves ambiguous the question of whether race/ethnicity or vehicle value better measures SES. To investigate this further, we used the 2013 Survey of Consumer Finances (SCF), which collects detailed data on the incomes and assets of American households. We extracted household-level SCF data for the United States on aggregate household vehicle value, average household vehicle value (gross vehicle value divided by the number of vehicles), race/ethnicity, household income, and household net worth. The raw correlations between race/ethnicity and household income, and race/ethnicity and household net worth, were somewhat smaller than those between vehicle value and income or net worth. In parsimonious linear regressions predicting income, the standardised coefficients associated with vehicle value were slightly larger than those associated with race/ethnicity (in absolute value). But in similar regressions predicting net worth, the standardised coefficient on being black or Hispanic was slightly larger in absolute value than the coefficient on vehicle value.

A second question, however, given our interest in equity, is whether our SES measures are good enough proxies for not just relatively lower income, but for some threshold of low income. Parking prices might burden the economically disadvantaged, but these racial/ethnic and vehicle value categories inevitably include a substantial fraction of well-off households. As we showed in Table 2, vehicle-owning households, who are more likely to use metered street parking than non-vehicle owning households, are much more well-off than households without vehicles. And while White drivers have higher household incomes than Latino drivers, Latino drivers do have an average household income of about $92,000 (according to the Census data in Table 2), which means that a substantial fraction of Latino drivers is affluent enough that street parking is not a substantial burden. Our analysis may be better served by a proxy that captures economic disadvantage more closely.

The SCF suggests that neither race nor vehicle value alone is a particularly strong predictor of low income or of low net worth. However, combining race and vehicle value yields two improved proxy measures that seem to better predict household income. In the SCF data, 37 per cent of Black or Hispanic households with vehicles in the lowest-value tertile were in the lowest quintile of household income, and 78 per cent of such households earned below the median household income. White households with vehicles in the high-vehicle tertile, conversely, have only a 21 per cent probability of being in the bottom income quintile, and only 50 per cent of such households earn below the median income. We therefore created two additional SES variables in our own observational data: one, a ‘low-income proxy’, indicating if a parker was Latino or Black and parked a low-value vehicle (about 14 per cent of our sample), and another, a ‘high income proxy’, indicating if a parker was White and drove a high-value vehicle (about 17 per cent of our sample).

3.1.5 Parking spell duration

Both overall and across SES groups, our observational data show that the average parking duration rose even as the average meter price increased (Table 4). Whites and Asians parked longer than Latinos and Blacks, and expensive vehicles stayed longer than inexpensive vehicles, but all groups parked longer, on average, in 2013 than in 2011. In percentage

Table 4
Average Parking Duration by SES Group (in Minutes)

Category	Round 1	Round 4	% change
Race/ethnicity:			
White	53	70	32
Latino	37	54	46
Asian	48	66	38
Black	52	58	12
Vehicle value (VV):			
Low	52	69	33
Medium	58	73	26
High	58	72	24
Combinations			
Latino/Black + Low VV	40	48	21
White + High VV	55	72	31
Total	55	71	27

Note: For the forty blocks observed in both round 1 and round 4.

terms, Latino durations grew most (46 per cent) followed by Asians and Whites (38 and 32 per cent), while the increase in duration for black parkers was only 5 per cent. The increase was somewhat larger for lower-valued vehicles than for higher. Still, by the end of the data collection period in 2013, the average duration of White parkers at seventy minutes was higher than that of Asian parkers at sixty-six minutes and of Black or Latino parkers at fifty-eight and fifty-four minutes, respectively. Finally, the high income proxy group (White drivers of high-value vehicles) increased their average duration by 27 per cent, while the average duration grew only 21 per cent for the low-income proxy group (Black or Latino drivers of low-value vehicles), despite starting from a much lower base. By the end of the fourth round drivers in our low-income proxy group had the lowest average duration of any group, and a by full ten minutes.

Table 5
Parking Sessions by SES Group

Category	Round 1	Round 4	% change
Race/ethnicity:			
White	1,921	1,373	−29
Latino	951	704	−26
Asian	538	396	−24
Black	301	251	−15
Vehicle value (VV):			
Low	1,597	1,006	−37
Medium	1,159	1,054	−9
High	1,128	949	−16
Combinations			
Latino/Black + Low VV	643	388	−40
White + High VV	624	484	−22

Note: For the forty blocks observed in both round 1 and round 4.

Table 6
Total Duration by SES Group (in Minutes)

Category	*Round 1*	*Round 4*	*% change*
Race/ethnicity:			
White	101,483	94,395	−7
Latino	34,521	37,758	9
Asian	25,924	25,658	−1
Black	15,456	14,438	−7
Vehicle value (VV):			
Low	82,381	69,759	−15
Medium	67,592	76,626	13
High	65,889	68,522	4
Combinations			
Latino/Black + Low VV	25,479	18,570	−27
White + High VV	34,455	34,928	1

Note: For the forty blocks observed in both round 1 and round 4.

As parking durations rose, parking turnover (the number of parking sessions) fell by 23 per cent overall, with variance by racial /ethnic group and vehicle value (Table 5). Turnover fell most (40 per cent) among Latino or Black drivers of low-value vehicles (our low-income proxy), and least among Blacks (15 per cent). Our high-income proxy group saw a 22 per cent reduction in turnover, substantially smaller than the reduction associated with the low-income proxy group.

The increased average parking spell duration combined with decreased parking spells combined to yield small decline in occupied minutes (about 1 per cent). The largest decline in occupied minutes was among our low-income proxy group, while only the high-income proxy group increased occupied minutes, albeit slightly (Table 6).

Why would durations rise even as prices rise? One answer is that SFpark relaxed time limits and made credit card and remote payments easier (Chatman and Manville, 2014). Two other potential answers involve either increased carpooling, or increased non-payment, by some or all SES groups. We examine these possibilities in turn.

3.1.6 Carpooling

Drivers facing higher prices could park for the same length of time, or longer, than they would at lower prices, but spread the cost over more people. Our data, however, suggest that carpooling hardly changed as prices rose. Average vehicle occupancy stayed at 1.4.[9] Among racial/ethnic groups there were no statistically significant changes in carpooling from round 1 to round 4 except among Latino drivers, among whom the average vehicle occupancy decreased very slightly from 1.6 to 1.5 occupants per vehicle (95 per cent confidence).[10] Similarly, there were no statistically significant changes in carpooling over this period for high-value and low-value vehicles. There was a statistically significant

[9]On the 40-r1&r4 blocks it was 1.394 in round 1 and 1.387 in round 4; on the 36-r1-r4 blocks it was 1.396 in round 1 and 1.395 in round 4. [table rnum $if2, c(mean occupants_clean) f(%7.3f) row].

[10]Example code: [ttest occupants_clean $if2 & raceeth_clean = = ‘Latino’, by(rnum)].

increase in occupancy for medium-valued vehicles, but this increase was small and practically meaningless, from 1.38 to 1.42 occupants. Among our high-income proxy group, carpooling went up slightly, from 1.31 to 1.37 occupants, and this was statistically significant at the 90 per cent level; while for the low-income proxy group, there was no statistically significant change. In short, our data suggest that carpooling does not explain differential responses to meter rate changes by SES group, and in particular, does not explain why lower-income groups did not respond to price changes very much.

3.1.7 Non-payment

Did drivers adjust to rate increases by acquiring and using permits more often, or by simply not paying? We can examine non-payment by group as share of parking sessions or a share of parked minutes. By either metric, it was common, accounting for over 40 per cent of parking sessions and over half of occupied minutes across all four rounds.

Non-payment can also be measured by examining non-payment without permits (which is illegal) and non-payment with permits (which may or may not be legal, given the prevalence of permit fraud). When looking at unpaid minutes including permits, we see that Black drivers on average used the most unpaid minutes, but had the lowest proportional increase in non-payment over time. Our low-income proxy group had relatively low levels of non-payment and a relatively small increase over time. Drivers in our higher-income proxy group, in contrast, had higher levels of non-payment and higher rates of increase. When we look only at definitively illegal non-payment, this finding changes a bit. Our low-income proxy group used more minutes without payment or permit in round 1 than our high income proxy (4.5 to 3.5), but by round 4 these positions had reversed, and the high-income proxy group was averaging almost ten unpaid minutes per session, compared to the low-income group at just under seven minutes. Q4

To summarise, non-payment is pervasive, but we see little reason within patterns of non-payment to explain why parking durations rose with price increases.

Table 7

Average Unpaid and Illegally Unpaid Minutes by SES Group

	Unpaid minutes, including permits			*Illegally unpaid minutes*		
Category	*Round 1*	*Round 4*	*% change*	*Round 1*	*Round 4*	*% change*
Race/ethnicity:						
White	20.1	30.0	49	5.1	9.3	82
Latino	13.8	25.9	88	4.3	7.4	72
Asian	20.5	31.3	52	4.5	8.8	96
Black	25.9	33.0	27	4.7	7.7	64
Vehicle value (VV):						
Low	26.6	38.2	44	5.3	7.9	49
Medium	29.0	38.0	31	8.7	9.7	11
High	26.5	35.0	32	3.4	9.2	171
Combinations						
Latino/Black + Low VV	16.9	22.5	33	4.5	6.6	47
White + High VV	19.8	29.1	47	3.5	9.8	180

Note: For the forty blocks observed in both round 1 and round 4.

Table 8
Dissimilarity Over Observed Blocks by Race/Ethnicity, Vehicle Value, and Combinations

	Race/ethnicity category				*Vehicle value class*			*Combined categories*	
Round	*White*	*Latino*	*Asian*	*Black*	*Low*	*Medium*	*High*	*Black/Latino + Low VV*	*White + High VV*
1	0.32	0.45	0.23	0.22	0.15	0.07	0.15	0.35	0.28
2	0.30	0.43	0.28	0.24	0.18	0.10	0.17	0.38	0.27
3	0.29	0.43	0.23	0.30	0.13	0.10	0.16	0.36	0.26
4	0.28	0.38	0.22	0.26	0.14	0.08	0.15	0.35	0.24

Note: Analysis restricted to the thirty-six blocks observed in all rounds. (These thirty-six blocks account for 13,445 parking sessions or 77 per cent of all observations made.) Results are similar for the forty blocks observed in both round 1 and round 4.

3.1.8 Heterogeneity across block faces over time

If higher prices displaced lower-SES drivers from more expensive areas, then as meter rates became more varied, driver SES should become more homogenous within block-faces, and more heterogeneous across them. Lower-priced options should be taken by lower-income drivers, and vice-versa. To examine this question, for each of our SES groups in each round, we created dissimilarity indices. These indices range from zero (perfect integration) to one (perfect segregation), and their value can be interpreted as the share of a given group that would have to be redistributed to achieve a perfectly representative distribution. So for example, a Black dissimilarity index for Round 1 of 0.40 would suggest that 40 per cent of non-Black parkers would need to be redistributed to generate a perfectly equal distribution of parkers by Black vs non-Black status in that round.

The indices (Table 8) do not suggest that such sorting occurred. In fact, blocks in our sample became somewhat more diverse as meter rates changed. For every racial/ethnic group except Blacks, the dissimilarity index fell over time. For Blacks the index grew slightly, from 0.22 to 0.26, but remained low in absolute terms (values over 0.5 are generally considered indicators of high segregation) and also lower than for non-Hispanic White drivers and Latino drivers. The dissimilarity index also fell for both low and high-valued vehicles, while rising a bit for medium-valued vehicles but never exceeding 0.09. Finally, for our low-income proxy group (Blacks or Latinos with low value vehicles) there was on average no change over the two-year period, starting and ending with a value of 0.35 (though the index temporarily inched higher in the intermediate rounds); while for our high-income proxy group (White drivers with high-value vehicles) the index consistently declined from 0.28 to 0.24 over the period.

This analysis suggests that raising prices on the sampled blocks did not result in more sorting across blocks by income, and if anything, there was less sorting by income — suggesting that there was not a taking up of lower priced options by lower-income households.

3.2 Regression analyses

We carried out regression analyses to control for additional factors that might affect price responses by the different SES groups. We examined two hypotheses, consistent with our descriptive analysis: First, whether when meter rates were higher, lower-income drivers were less likely to park at all; and second, whether higher meter rates caused lower-income drivers to park for less time.

Our data allowed us to examine parking behaviour in three ways: by comparing vehicles to each other, comparing blocks to each other at the same time of day, and looking at changes in block-level use over the two-year study period, as described below. We describe the first approach in detail in Section 3.2.1, while the second and third approaches, conducted essentially as robustness checks on the first analysis approach, yielded consistent but often statistically insignificant results due to a reduction in sample size caused by aggregation, as we describe briefly in Section 3.2.2.

3.2.1 Regression analysis of vehicle-level data

Using vehicle-level data (more than 17,000 observations), we first analysed the number of minutes parked per vehicle as a function of the meter rate. We estimated separate regressions for each racial/ethnic group and each vehicle value category, anticipating stronger price responses for Black or Latino drivers, for drivers of lower-valued vehicles, and for those in both categories. Because drivers could react to price increases by not parking at all or parking for less time, we estimated three types of model: a logit model for the likelihood of any given parker being within the category of interest (for example, being Latino or driving a low-value vehicle); an OLS model for the duration of a parking spell by race/ethnicity or vehicle value, given that the person parked the car; and a third, combined model, in which the dependent variable was the number of minutes parked if the driver or vehicle was in the category of interest, and was set to zero otherwise. We estimated this final model using Tobit. (For example, when analysing White drivers, the dependent variable was set equal to the number of minutes parked if the driver was White, and set equal to zero if the driver was non-White.)

Each regression included the following controls: the round of observation; the timeband (morning, midday, or afternoon); the day of the week; the month; the number of workers in the nearest Census block (from the Census's 2011 Longitudinal Employer-Household Dynamics data set); fixed effects for each block face; and dummy variables indicating whether a disabled placard was displayed,[11] whether the day was sunny, and whether the vehicle was parked on a control block.

The results are shown in Table 9 in three columns. The table shows the meter rate coefficients for twenty-seven regressions: three model types (presence, duration, and presence + duration) for the nine SES categories (race/ethnicity, vehicle value class, and the combination variables). We focus our discussion below on the combined SES proxies: Black and Latino drivers of low-valued vehicles, and White drivers of high-value vehicles.

Table 9's first column shows meter rate coefficients measuring the likelihood that a parked vehicle is in a given category (for example, a White driver or a low-valued vehicle). Notice that in no case is the meter rate negatively and statistically significantly correlated with the likelihood of parking. In other words, the meter rate simply does not predict the likelihood of parking, contrary to expectation. This result could be explained by the endogeneity of meter rates to demand — that is, meter rates rise on blocks where people want to park. But demand is derived from location-specific attributes, which our

[11]We include the placard dummy because some paying vehicles nevertheless displayed placards.

Table 9
Meter Rate Coefficients for Parking Likelihood and Duration, by SES Group

	Presence of vehicle (Logit)[1]	*Duration once parked (OLS)*[2]	*Presence + duration (Tobit)*[3]
White driver	0.064*	−27.889***	014.014***
Latino driver	−0.013	−15.69***	−5.555**
Black driver	0.053	−30.579***	−3.973
Asian driver	0.053	−25.686***	−4.339
Low-value vehicle	−0.056	−27.707***	−18.003***
Medium-value vehicle	−0.018	−32.117***	−16.469***
High-value vehicle	0.066*	−29.197***	−9.7***
Black/Latino driver, low-value vehicle	−0.031	−16.049***	−5.962*
White driver, high-value vehicle	0.089*	−23.355***	−1.857

Notes: * = 90 per cent confidence level; ** = 95 per cent; *** = 99 per cent.
[1]N = 17,359.
[2]N varies depending on group, ranging from 1,309 to 8,558 observations.
[3]N = 17,189 (durations less than one minute excluded).
Source: Observational survey by the authors, all rounds (pooled vehicle-level data). Variables included in every regression but not shown: employment within the proximate census block (measured using 2011 LEHD data); and dummy variables, representing: round of observation; time band; month of year; day of week; block fixed effect; weather (sunny); and control block status.

regressions control for. Note that for White drivers of high-value vehicles, the likelihood of parking is positively correlated with the meter rate, though only at the 90 per cent level of statistical significance; and the same is true for White drivers overall and high-valued vehicles overall. We see, in short, some statistically weak evidence that higher meter rates cause a higher probability of parking among those of higher income, consistent with expectation.

Table 9’s second column shows OLS output for equations where the dependent variable is the duration of a parking spell, conditional on having parked there. All groups park for less time at higher price meters, controlling for other factors, although drivers in the low-income proxy category are among the least sensitive to price increases. A $1 per hour increase is associated with Black or Latino drivers of low-valued vehicles parking for sixteen minutes less on average, compared with the high-income proxy group (White drivers of high-value vehicles) parking an average of twenty-three minutes less. In a separate, pooled analysis this difference was statistically significant at the 90 per cent level.[12] These results thus provide no evidence that higher meter rates will disproportionately reduce parking duration among lower-income parkers. If anything, they may suggest the opposite.

The OLS results alone (in column 2) neglect the probability of parking in the first place, while the logit results (in column 1) capture that probability but ignore duration. Table 9’s final column shows output from Tobit models that combine the likelihood of parking with the duration of the parking spell, yielding a rate of net use in response to the meter

[12]Note that this pooled analysis was possible for the OLS models but not for the logit or Tobit models because the latter model types assign a ‘zero’ for subgroups outside the group of interest.

rate.[13] These regressions yield somewhat inconsistent results. For our low-income proxy group, Black or Latino drivers with low-valued vehicles, a $1 meter rate increase is associated with about six minutes less of net use, but at a low level of statistical significance (90 per cent). There is no statistically significant association, in contrast, between the meter rate and net use for the high-income proxy group, that is, higher-value vehicles with White drivers. While at first blush this suggests a difference between our low-income and high-income proxy groups, the difference between the two coefficients (-5.96 and -1.8) is actually not statistically significant, based on comparing the confidence intervals. Adding to the inconsistent results is the fact that White drivers appear to have a much larger net response to the meter rate than the other racial/ethnic groups, while lower- and medium-valued vehicles, with very similar net responses, have a somewhat larger net response to the meter rate than high-value vehicles. In short, these results again emphasise that whatever differences in meter rate responsiveness exist among SES groups, they are not large and they often seem to be ambiguous, which is contrary to our hypotheses.

3.2.2 Robustness checks: analysis of block-level cross-sectional and longitudinal data

As a check on our results, we conducted two further sets of regressions, which to conserve space we do not show here because in the end they did not provide additional important information or insights. The first set of regressions analysed the share of total minutes parked and the number of sessions by SES group measured for timebands for each block for each observation round. Comparing block-timebands to each other across rounds allowed us to compare the share of occupied time consumed by each group at different meter rates over the two-year observation period, and thereby proved a more direct way to account for usage and duration. While the advantage of using block-timebands instead of vehicles is that this can be more directly used to measure displacement caused by price increases, the disadvantage is that it reduces our sample size from more than 17,000 (all observed vehicles) to 580 (three timebands for each block, for each of the four survey rounds). However, our results from this analysis did not depart substantially from the vehicle-level results reported above. Additionally, in these block-timeband regressions we examined whether drivers reacted more strongly as meter rates became higher and lower over time — if a rate rising from $5 to $6, in other words, might yield a larger behaviour change than one rising from $1 to $2. We found only one significant difference, which was that the responsiveness of Latino drivers to price appeared to decrease over time, contrary to expectation. Our second robustness check consisted of longitudinal regressions that compared blocks to themselves over time. This approach is particularly robust to misspecification errors, because it implicitly controls for unobserved differences between blocks, as well as unobserved general trends across all blocks (such as an improving city economy or changing racial composition). However, it is even more costly in sample size: we have only forty-one unique blocks where prices changed, and could not observe all of these blocks in all four rounds, leaving us with 108 total observations. Perhaps for this reason, the meter rate coefficients were uniformly statistically insignificant across SES groups.

[13] Ideally we would combine these models into a Heckman sample selection model rather than using Tobit, but Heckman models require a plausibly exogenous predictor for the first level equation, which was not available in our data.

3.3 Trip length and trip purpose

Both our descriptive analysis and our regression results suggest very little in the way of differential responses to meter prices, and even in some cases that higher-income drivers might be more sensitive to price increases than lower-income drivers. The fact that lower-income drivers do not have markedly stronger responses to meter rate increases might arise if this group has fewer substitutes for on-street parking. Why might this be? Perhaps lower-income drivers use street parking for trips whose time or location cannot be changed (for instance to work); for longer trips (which might rule out using to other modes); for trips with poor alternatives to paid on-street parking (such as access to off-street parking at work or via relatives/friends); or in cases where they have little information about existing nearby lower-cost street parking.

Our intercept survey, by providing each driver's home zip code and trip purpose, offers some insight into these possibilities. We used the distance from the driver's parking spot to their reported home zip code as a proxy for trip distance, though it is of course possible that the trip did not originate at home.[14] If lower-income drivers were coming from longer distances, alternative modes (such as transit, walking, or cycling) might be less possible for them. When analysing this using geocodes and travel route calculations, however, we found no evidence that distance from home to the parking location was higher among the different SES groups. (To save space, we do not show these results.)

Trip purposes, however, did vary by SES. In particular, the differences between our proxies for low-income and high-income drivers were sizeable and statistically significant. We show only this analysis, although we did see similar patterns for the simpler SES groupings as well (Figure 3). Black or Latino drivers of low-value vehicles were more than 100 per cent more likely to report parking for discretionary reasons like errands and personal trips, and accessing their homes. White drivers of high-value vehicles, in contrast, were more than 100 per cent more likely to report parking for discretionary reasons such as meals out and social activities. All other households tend to fall in the middle, with a monotonic increase or decrease, as Figure 3 shows — except for 'work' trips, for which the 'other middle income' group is substantially more likely to be parking than either low-income or high-income proxy households.

Thus the nature of the trip could help explain the fact that lower-income parkers do not in our data have a larger response to price than higher-income parkers. This explanation is far from ironclad, since even people who must drive to a particular place at a particular time might still have some choice over where to park: as we noted above, almost every block in our sample with high meter rates was within a short walk of blocks with lower rates. So positing that lower-income parkers could not avoid making trips raises the question of why they did not, essentially, save money by 'parking around the corner'. One potential answer is that low-income drivers may not be aware that prices are lower nearby. If this is the case — and our data cannot tell us if it is or not — it suggests that better information might be a straightforward and inexpensive way to blunt equity impacts of higher prices, as long as lower-priced blocks are available nearby (as was the case for SFpark).

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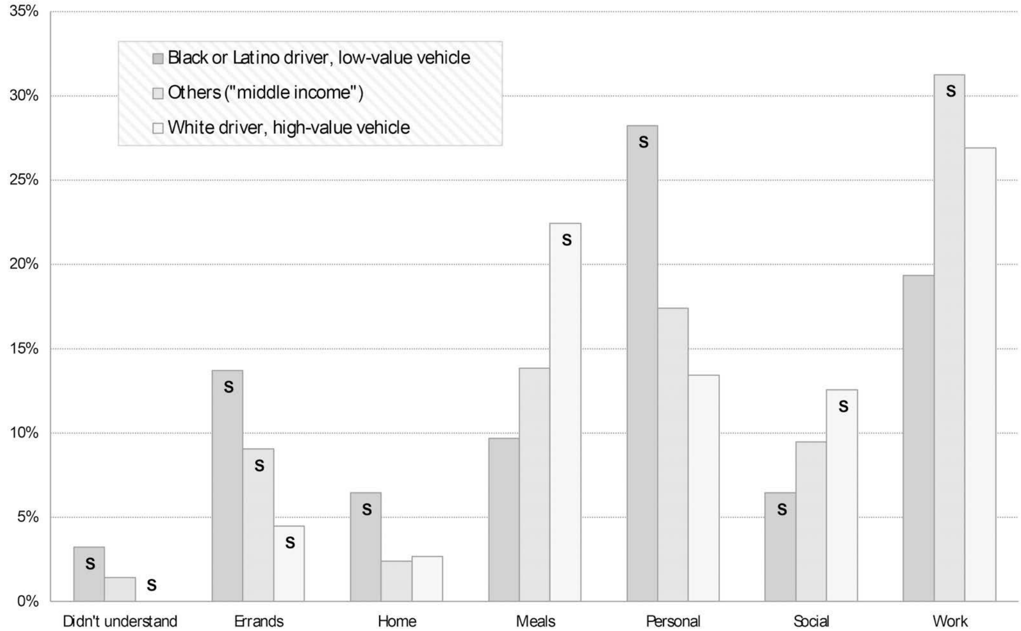
[14] We obtained these distance measurements from the Google Maps API.

Figure 3
Trip Purpose Share by Household Income Proxy (Combined Race/Ethnicity and Vehicle Value)



Note: An 'S' indicates that a category is significantly different from the two others, either individually or jointly. Two 'S's means only those two categories are significantly different from each other. Three 'S's means all categories are significantly different from each other.

4.0 Discussion and Conclusions

Does market-priced parking disproportionately burden lower-income households? To date this question has not been empirically addressed, both because market-priced parking has been rare and because measuring the behaviour and SES of people who park is difficult. In this article we have made a first attempt at an answer, by using SFpark, San Francisco's dynamic-pricing experiment, as an opportunity to gather original data on parking behaviour as prices changed over time. Our results illustrate the challenge confronting anyone who tries to measure the impact of higher parking prices on the poor. Absent direct measurements of income and the ability to follow parkers over time, we must make inferences based on imperfect proxies. Much more research is needed in this area.

That being said, we find little evidence that higher-priced parking displaces lower-income drivers, either by reducing their parking durations or leading them to park less overall. We find that lower-SES groups are probably over-represented at paid street spaces relative to their population share overall. We also show, however, that across a broad sample of dynamically priced parking spaces, rate increases did relatively little to change the socioeconomic composition of on-street parkers, and had no apparent effect on spatial segregation by SES. Before, during, and after SFPark, lower-SES drivers used street parking less than higher-SES drivers, but like all parkers they increased their parking durations: across all groups, the number of vehicles parking fell, and the duration of each session rose. Neither differences in non-payment nor differences in carpooling help explain the failure for prices to reduce the use of parking by those of lower income.

Our regressions yielded somewhat contrary findings, but are consistent in that they do not provide evidence for a significantly stronger response to meter rate changes by lower-income parkers. This is notable, and contrary to theory and empirical expectation. Drivers in our high-income proxy group were more responsive to prices in terms of minutes parked than were drivers in our low-income proxy group. When we analysed parking duration combined with propensity to park at all, we found some statistically weak evidence that low-income drivers may be slightly more responsive to meter rate increases than high-income drivers.

The inference we tentatively draw from these results is that higher prices make lower-income drivers less likely to use street parking, but less sensitive to prices once they have parked. This reduced sensitivity might owe to lower-income drivers using street parking in a less discretionary way — only important trips justify using it, and important trips are less likely to be altered once made.

Some further caveats are in order. SFpark was a landmark experiment, but covered only 25 per cent of the city's metered spaces; prices in many areas rose slowly; and prices were not allowed to rise to their market level in many instances. A more comprehensive dynamic pricing programme, of the kind often envisioned by pricing proponents, might well yield bigger differences in the behavioural responses of different SES groups. Further, our data do not permit us to measure welfare. We cannot know how much people who parked valued their spaces, nor can we measure the loss of utility by those whose trips were truncated or displaced. As such, we cannot render a judgment about the net welfare impacts of SFpark based on these findings.

That point yields our final observation. To the extent we have documented a disproportionate burden on the poor (and the evidence is at best suggestive), the policy implication is not to forego market-priced street parking, but instead to compensate those who are strongly negatively affected. Local redistribution is difficult, but priced parking yields revenue that could be channelled to any who are harmed.

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U.S. Census Bureau. American FactFinder. Generated by Paul Sohn using American FactFinder, http://factfinder2.census.gov (17 July 2014). Q6

Appendix

Figure A1
Civic Centre, Block-by-block Prices, May 2013

Figure A2
Financial District, Block-by-block Prices, May 2013

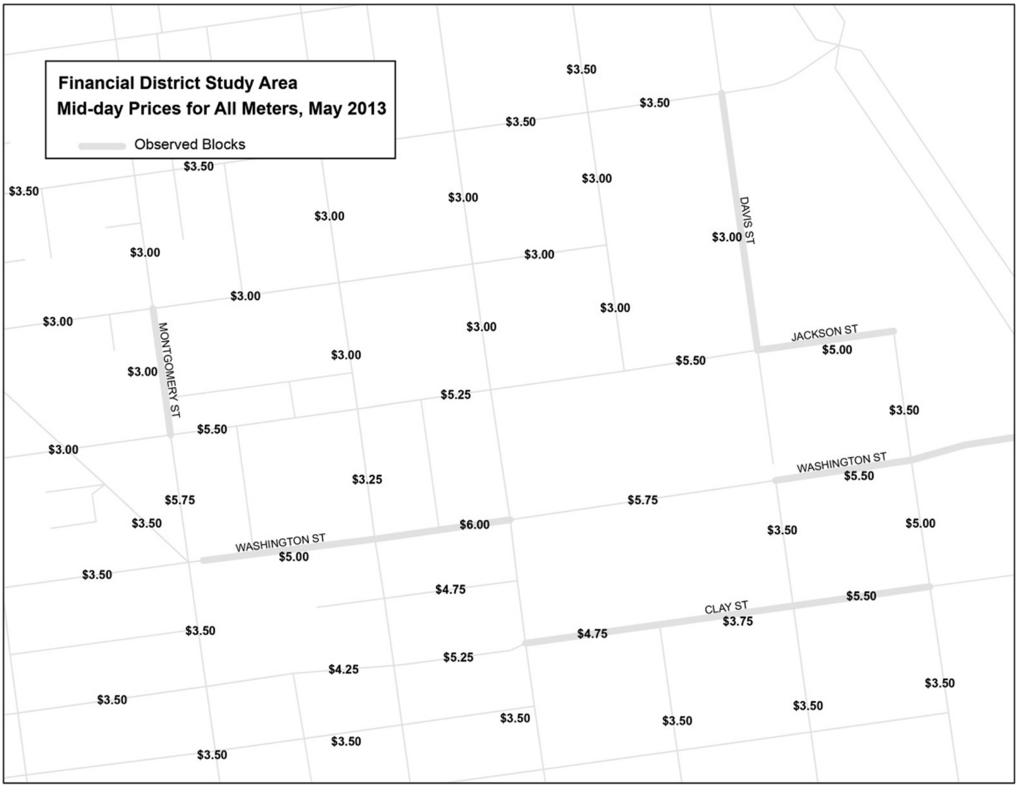


Figure A3

Mission District, Block-by-block Prices, May 2013

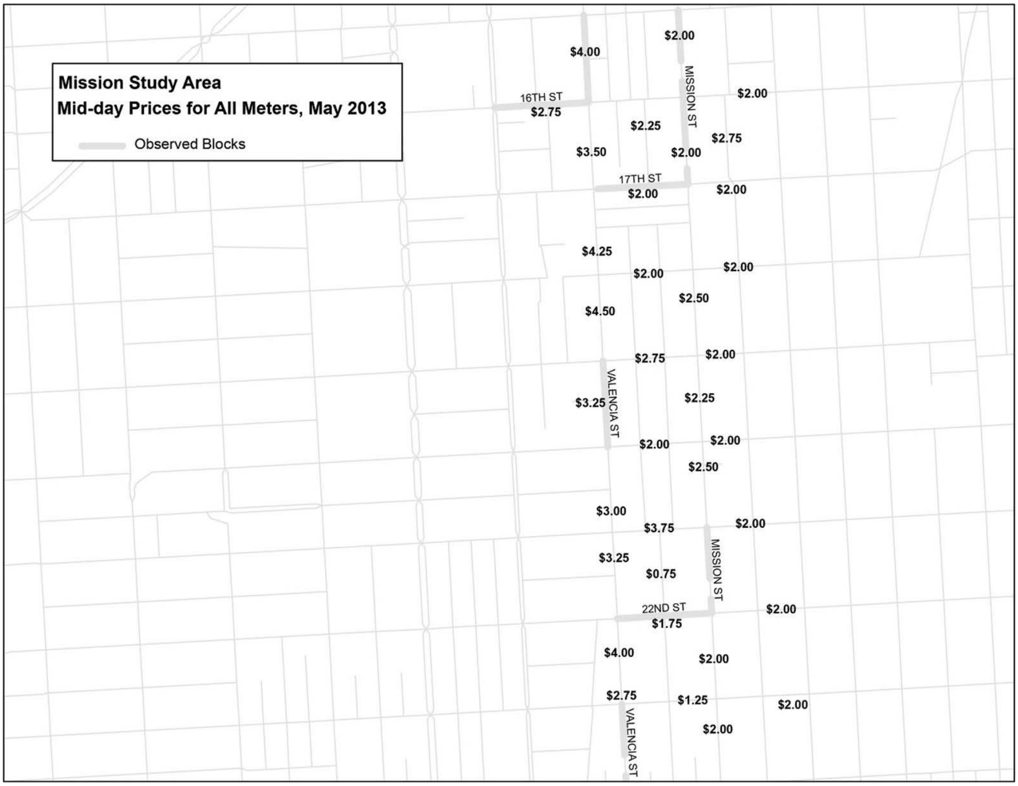
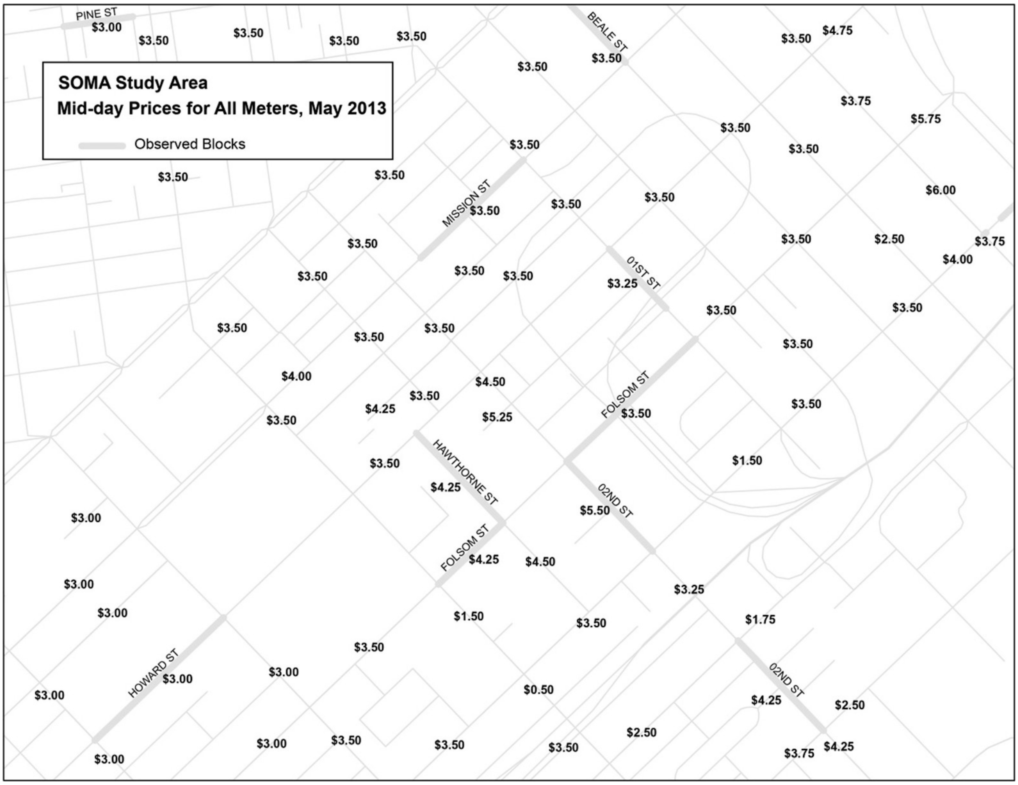


Figure A4
SOMA Study Area, Block-by-block Prices, May 2013



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Paper Authors Chatman and Manville

1 Khoeini and Gunstler, 2014: Koeini and Guenlser in references.

2 Miller *et al*., 2007: 2002 in references.

3 [fn 8] Charles *et al*., 2008: 2009 in references.

4 When looking at unpaid minutes ...: should Table 7 be referenced in this paragraph? (It is currently not referenced anywhere.)

5 San Francisco Metropolitan Transportation Authority (2014): does not appear to be referenced directly in the text.

6 U.S. Census Bureau. American FactFinder: does not appear to be referenced directly in the text.

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Theory versus implementation in congestion-priced parking: An evaluation of SFpark, 2011e2012

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Shortages of street parking can cause cruising, a major source of urban congestion. We used SFpark, a federally funded experiment in market-priced parking in San Francisco, to study how changes in meter prices influenced on-street parking availability. We supervised observations of more than 13,400 vehicles parked on a subset of dynamically priced and control blocks at three points in time during 2011 and 2012. Repeated-observation, change-on-change regressions show that when prices rose, the block-level occupancy of parking fell, suggesting that SFpark worked as intended. But blocks where prices rose showed no discernible improvement in parking *availability*dthe share of time at least one space on a block face was vacant. Price increases also had no association with other factors we would expect to be influenced by price, including parking duration, vehicle turnover, and carpooling. These relationships were robust to controlling for the parking zone, the previous price level, nearby employment, and the weather. A price system designed to improve average occupancy may not improve parking availability, and thus may not reduce cruising. Cities trying to reduce cruising may need to adjust prices based on minimum vacancy, and price changes may need to be larger in many cases.

1. Introduction

In busy central cities, drivers searchingdor “cruising”dfor street parking create large amounts of traffic congestion, pollution, and other externalities. Cruising occurs where street parking is scarce, which is typically where on-street spaces cost less than off-street spaces, or are otherwise underpriced (Shoup, 2006). Transportation economists such as Shoup (2005 and 2011) and Vickrey (1954) have argued that if cities priced street parking properly, drivers willing to pay for it would easily find spaces, while price-conscious drivers would use cheaper spaces off-street or farther away; share parking costs by carpooling rather than driving alone; or avoid parking costs altogether by walking, cycling, taking transit, traveling at another time of day, or forgoing their trips. Correct pricing would thus reduce or eliminate congestion related to parking search.

Congestion-priced parking is in theory similar to road pricing. But where in many cities all roads are free, in most cities drivers are accustomed to paying for parking at least some of the time. In dense parts of cities, therefore, dynamic parking pricing might be easier to implement, and more effective, than road pricing. But the evidence available on this question is limited, primarily because road pricing remains rare, and market-priced street parking has until recently been nonexistent. What we know of road congestion pricing suggests that programs are initially unpopular but earn wider acceptance over time, partly because they deliver quickly on promises of reduced congestion (e.g., Harsman & Quigley, 2010). When London implemented its congestion charge, the price of driving into the city’s financial district rose overnight from zero to 5 pounds, and traffic in the charging zone fell almost immediately (Santos, 2008). After six months, traffic entering the zone was still 25% lower than before the program began. Similarly, the first year of Singapore’s road pricing program saw traffic entering the priced zone fall 44%, and during Stockholm’s congestion tolling pilot program traffic levels fell 10e13% (City of Stockholm, 2006; Holland & Watson, 1978). Despite attaching high prices to previously free roads, all of these programs received majority approval, either in direct votes or public opinion polls.

Can congestion-priced street parking deliver similar results? This study examines one of the first tests of this question: the SFpark program in San Francisco. The San Francisco Municipal Transportation Authority (SFMTA) launched SFpark in 2011 in

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cooperation with the US Department of Transportation, which helped fund the system through the Value Pricing Pilot program of the Federal Highway Administration. SFpark uses thousands of computerized "smart" meters, along with sensors embedded in the pavement under parking spaces, in several parts of San Francisco. The program's explicit goal is to reduce cruising (its slogan is "live more, circle less") and to thereby increase the speed and reliability of SFMTA's buses and trolleys, reduce parking time search and frustration, and make walking and cycling safer. So do higher parking prices generate more vacancy, and by implication, reduce cruising and local congestion?

To answer this question, we draw on thousands of hours of curb parking observations from 50 priced and control blocks that we carried out at three different times in 2011 and 2012. We examined SFpark's effects using multiple metrics, focusing not just on average occupancydthe measurement SFpark employsdbut also on the share of time at least one space was available on each block, as well as parking turnover and duration, vehicle occupancy, and non-payment. Our results suggest that SFpark is very different, at least in the early stages, from comparable experiments in road pricing. Where road pricing has typically been associated with rapid and substantial reductions in peak hour congestion, we find that after a full year of SFpark, parking price increases were not associated with greater parking availability or with other metrics that would suggest reduced cruising. While price increases are associated with reductions in average block occupancy (the metric SFpark uses to make its price adjustments) we find little or no relationship between price increases and increases in minimum vacancy, nor between higher prices and shorter parking spells, higher turnover, or more carpooling.

We offer three possible explanations for these results. First, SFpark based its price adjustments on average occupancy, seeking to keep all blocks 60e80% occupieddthough its desired policy outcome, less cruising, was arguably better related to the share of time that at least one space is available on the block. These two metrics are not equal: a block with 80% monthly average occupancy can still have many hours when it is entirely full. Second, for understandable political reasons, SFpark did not simply let the price of parking float. The program instead made small adjustments over time, and restricted how fast and high prices could rise. Third, SFpark made price adjustments only after it had significantly reduced or removed limits on parking duration, and made parking easier to pay for by installing meters that accepted credit cards and remote payment. The effect of sharply falling time limits and easier payment may have diluted the effect of rising prices.

In sum, we find that while congestion-priced parking is conceptually quite similar to congestion-priced driving, the SFpark experience thus far suggests that in practice, congestion-priced parking might play out quite differently. The way agencies decide to make price changes can have a substantial impact.

2. About SFpark

Prior to SFpark, meter rates in San Francisco varied by neighborhood but not time of day or day of week (Table 1). Most of the meters were old, coin-operated devices. Because prices were rarely high enough to generate turnover, almost all metered spaces had 1- or 2-h time limits. The highest street rate was $3.50 per h; by way of comparison, the median off-street parking rate in the downtown area was $10 per h in 2012 (Colliers International, 2013). Further, the SFMTA rarely changed the rates citywide. During its budget process, the agency's board would occasionally vote to change rates, but there was no fixed timetable for reviewing meter rates, nor any formula for changing them (San Francisco Metropolitan Transportation Agency, 2011).

SFpark sought to make prices responsive to demand, and to make price changes more transparent and predictable. The agency selected eight "treatment" neighborhoods and four control neighborhoods, replaced thousands of the older coin-operated meters with smart meters that allowed both credit card and remote payment, and placed magnetic sensors in the pavement of on-street spaces to measure occupancy. The sensors and meters relayed information wirelessly to SFMTA, and beginning in 2011 the agency used the data to set meter rates that varied by block, time of day (morning, midday and afternoon, which the agency called "timebands") and day of week (weekday versus weekend). The SFMTA based these price adjustments on the average occupancy for each timeband on each block over the course of about a month's worth of sensor data. Any price for one of the three timebands on a block could rise or fall depending on the calculated occupancy levels (Table 2). Thus if a block was congested in the morning but largely vacant in the afternoon, the agency would raise the rate for the morning timeband but reduce the rate in the afternoon. In short, the agency replaced a system of neighborhood rates that changed infrequently and opaquely with a transparent system for changing prices over smaller units of time and space.

These rate changes were not perfectly responsive to demand, because SFpark limited both the size and frequency of price changes. The agency posted new rates on a monthly or bimonthly basis, and could increase the rate by at most 25 cents per h while reducing the rate by 50 cents at most. In addition, the agency imposed a price floor of 25 cents, and capped the price at $6 per h for most blocks. Nor were price adjustments the only changes SFpark made. Prior to the program's first price changes, the city relaxed the 1e2 h time limit on many blocks up to 4 h, and on the remaining blocks eliminated time limits altogether. The city also introduced credit card and remote payment options.

By most accounts, SFpark has not greatly changed the average hourly parking rate in the pilot zone. The *San Francisco Examiner* reported that between April 2011 and December 2012 the average parking price in the SFpark area had fallen from $2.73 to $2.59, and that 6% of SFpark's meters had reached the $0.25 price floor (Reisman, 2012). Similarly, Pierce and Shoup (2013) reported that average prices fell by 1% over the program's first year (August 2011 through May 2012). But the area-wide average conceals substantial variance across time and place. Prices tended to fall in the morning and rise during the midday and afternoon; some neighborhoods saw consistent price increases while others had declines. By April 2013, SFpark had announced ten on-street price adjustments, and on each occasion a plurality of meters saw no rate change. Only in the final three adjustments in 2013 did the share of meters where prices rose exceed the share where they fell. For example, in the

Table 1
Parking rates and locations prior to SFpark.

Zone	Price per hour
Downtown	$3.50
Downtown Periphery	$3.00
Fisherman's Wharf	$3.00
Other Commercial Districts	$2.00

Table 2
Criteria for parking rate changes, *SFpark*.

Average block-side occupancy	Rate change/h
Under 30%	−$0.50
30e60%	−$0.25
60e80%	No change
Above 80%	þ$0.25

April 2013 adjustment, 22% of meters increased in price while 20% decreased.

Did these price changes improve availability and reduce cruising? In 2012 the *New York Times* analyzed SFpark data and reported that three-quarters of the program's blocks had either met their occupancy targets or were "moving toward them" (Cooper & McGinty, 2012). This is an ambiguous judgment, however: a block can be "moving toward" some target occupancy level, yet be quite far from it. Millard-Ball et al.'s (2013) simulations suggest that vacancy improved significantly enough to reduce cruising. But Pierce and Shoup (2013) used SFMTA data on approximately 5300 block-level price changes and found that in about a third of cases, price increases were associated with *increases* in average occupancy.

To some extent conclusions about SFpark are limited by the available data. SFpark's meters and sensors show if spaces are occupied and whether vehicles have paid for their time, but apparently do not allow the agency to calculate vehicle turnover or the duration of parking spells.[1] The sensors also cannot provide information on whether drivers double park (either to avoid paying or because there are no spaces available), nor on whether parkers are responding to price increases by carpooling in order to share the higher cost. Neither can sensor data distinguish between types of non-payment. Some non-paying drivers are simply scofflaws, while others have credentials, such as disabled placards or government tags, that allow them to park legally without paying (e.g., Manville & Williams, 2012).

All these measures are relevant, because drivers may react to price changes in ways that only indirectly change average block occupancy, or that do not change it at all. For example, as prices rise more vehicles could park for shorter periods of time. While this higher turnover could help businesses, it might not alter average occupancy, and might even increase local traffic. Drivers could also respond to higher prices by carpooling, but this would change vehicle occupancy without necessarily changing parking-space occupancy, and thus might not change parking availability. And of course if drivers manage to avoid paying at all, price changes may have little impact on any of these measures. Our data collection focused on these behaviors that SFpark's sensors cannot record.

3. Data collection and variable construction

We studied about 40 block faces in four of the experimental zones (Mission Street, the Financial District, Civic Center, and South of Market, or "SOMA") along with 9 "control" block faces nearby (Fig. 1, below). The control blocks were similar to the experimental blocks in that they had smart meters and relaxed parking time limits, but different in that their prices did not change. We initially used random stratified sampling to choose block faces, with our strata being the four selected experimental zones and nearby control blocks. However, it became quickly apparent that under SFpark's price-change procedures many of our randomly-selected blocks would not undergo price changes because SFpark's pre-program data collection, available on its web site, showed that these blocks were already within the target occupancy range. Our budget restricted our sample size, so it was importantdif we were to have robust statistical testsdthat a large share of the blocks we observed undergo price changes. We therefore replaced some of the randomly-selected blocks by introducing an additional level of stratification, randomly sampling blocks where the average occupancy levels were high enough to trigger price changes.

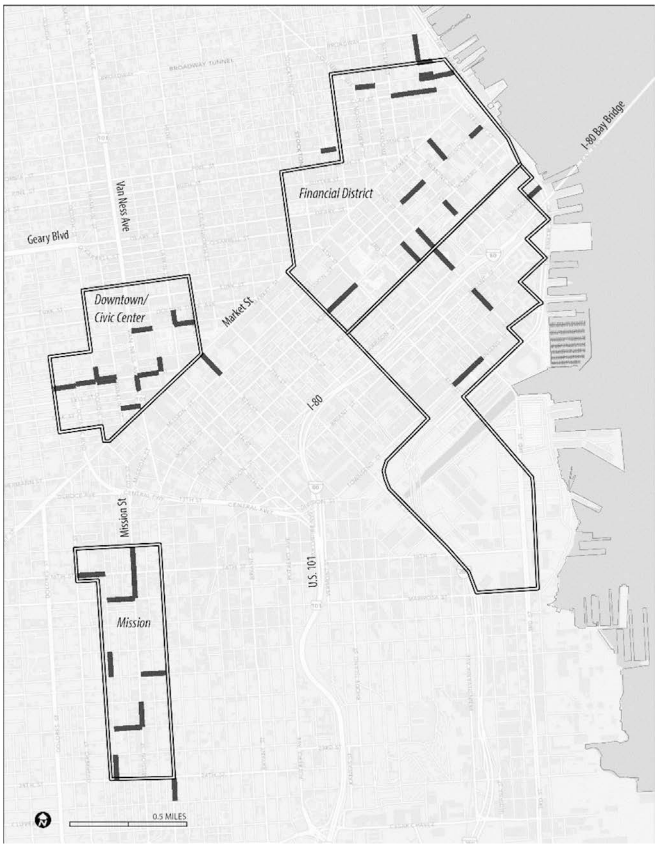

Fig. 1. Map of blocks in sample (shown: blocks observed both in round 1 and round 3).

We carried out three rounds of observations, and in each round employed 17e18 student surveyors. The surveyors took shifts and worked in pairs to observe a full day of parking sessions on each block face, typically from 7 or 9 am until 6 pm. Observing block faces for an entire metering period (following procedures similar to Manville & Williams, 2012) allowed us to collect not only arrival and departure times for vehicles at individual meters on each block, but also data on vehicle occupancy, double parking, and non-payment by type. We attempted to survey about two weeks after SFpark announced price changes, but our average in practice was four weeks after a price change. In 97% of cases at least a week of adjustment time elapsed between price changes and data collection.

We conducted our first observations in May 2011. At this point SFpark had installed smart meters and removed time restrictions, but not made any price changes. The second round of observations started in late October 2011, after price changes had occurred in August and October. Our surveyors completed this round in January 2012. The final round of observations began in May 2012 after prices changed earlier that month.[2] In total our surveyors observed 13,431 parking sessions, over three observation rounds of about 50 block faces three times each. Fifty is a small number relative to the total number of blocks in SFpark, but a limited budget forced us to trade breadth for depth. While our continuous observation surveys yield far more detail than sensor data, they are costly. The SFMTA, by virtue of its sensor data, already has the ability to conduct a broad analysis of the SFpark program, as do researchers who access

[1] Per a request received by the lead author from SFMTA for turnover and duration data from this study.

[2] We continue to conduct observations, but the May 2012 observations were the last we were able to prepare and analyze for this article.

its public database. Our approach therefore complements and expands upon the agency's data collection.

SFpark varies its prices by block and timeband. The morning timeband is from the start of metering, at 7 or 9 am, until noon; the midday timeband, from noon to 3 pm; and the afternoon/evening timeband from 3 pm until meters turn off, typically 6 pm. Two or three blocks had only two timebands; on those blocks the city turned meters off around 3 pm to convert parking lanes into traffic lanes. Because we collected complete data on between 47 and 49 blocks for a full day for three survey rounds in 2011e2012 and because our dataset is summarized for timebands within blocks (observed on weekdays only), we have 446 block-round-timeband observations in total. We used these observations to measure how price, occupancy, vacancy, and other measures changed between rounds 1 and 2, rounds 2 and 3, and rounds 1 and 3, for between 141 and 143 block-timebands.

Parking pricing is intended to reduce cruising, but cruising is notoriously difficult to measure (Shoup, 2006). Cruising is caused by a shortage of street parking spaces, however, which can be measured. Further, as we described above, drivers might respond to price changes in other ways that can affect parking occupancy or vacancy, and these are also measurable. To construct our variables we expanded our dataset of parked vehicle observations into a minute-by-minute report about the characteristics of parking spells for each space on each block, which yielded a database for each round of data collection consisting of over 300,000 observations. We then summarized this information to the block-timeband level. Using these summary data, we constructed nine dependent variables. Twodaverage occupancy and minimum vacancydare block-face availability measures that are directly related to cruising. The remaining measures help us better understand how driver behavior responds to price changes and consequently affects the availability of parking on the block.

3.1. Average occupancy

We defined average block occupancy as the percent of available parking-space minutes on a given block face. For example, if a block has 10 parking meters and we observe it for a 3-h timeband, then it has 1800 potential minutes of occupancy. If vehicles are parked for 540 of those available minutes, the block-timeband has 30% occupancy. We believe this measure is equivalent to the measure SFpark uses to make price changes, although we measure it for one day while SFpark uses an average of many days.

3.2. Parking availability

We define parking availability as the share of time at least one space on the block face is vacant. This measure is arguably a better metric of reduced cruising than average occupancy, because the occupancy measure does not capture how often parking is available on the block. If the 540 occupied minutes we mentioned above resulted from ten cars parked at the same time during one congested hour, drivers arriving during that hour would fail to find a space, and would be likely to cruise, even though the timeband's average occupancy would be low. Drivers search for parking spaces, not average occupancies. Average occupancy can improve from two directions: a price decrease could push occupancy from 75 to 85%, while a price increase could push it from 95 to 85%. But many of pricing's potential benefits are found in a specific unidirectional move: moving occupancy from 100% (zero vacancy) to whatever percentage equates to one space being available, which will vary depending on the number of spaces on the block. The largest externality of mispriced street parking is the time and mileage spent searching for a parking space, and making at least one space visibly available at all times is the most direct way to reduce that externality.

Our remaining dependent variables measure how price changes influence parking behavior, and hence both average occupancy and parking availability. These variables include the average duration (in minutes) of a parking spell, and the average hourly vehicle turnover per space. We expect price increases to free up space by decreasing duration; all else equal, consumers should demand less of a higher-priced good. The likely effect of price increases on turnoverdthe number of vehicles using any given spacedis ambiguous. Higher prices could reduce not only the amount of time vehicles are parked (increasing turnover) but also the number of vehicles parking (reducing turnover). Since one of SFpark's goals is to make spaces available, increased turnover may be a better measure of program success.

Our fifth dependent variable is vehicle occupancy. Our surveyors recorded the number of occupants in each vehicle to account for the possibility of increased carpooling. Studies of road pricing have shown that carpooling increases dramatically in response to price increases (Federal Highway Administration, 2009), and drivers might respond similarly if the cost of street parking rises, making more spaces available. Our sixth dependent variable is the frequency of double parking. Our surveyors recorded the number of times per hour that any vehicle was parked in the traffic lane. Drivers may double-park to make drop-offs and pick-ups more quickly without having to park; to access a destination if no legal parking space is available on the block; or simply to avoid feeding the meter. In either case double-parking can cause road congestion. Higher prices could lead to higher vacancy or lower occupancy, therefore reducing the motivation for the second type of double-parking, but higher prices could also increase the incentive to double-park in order to avoid payment.

Our final three dependent variables measure non-payment: the share of time that vehicles are at meters but not paying, the share of time vehicles are *illegally* unpaid (without a credential that exempts the vehicle from paying), and the share of time occupied by vehicles with disabled placards. We investigate these measures because if drivers react to higher prices by finding ways to avoid paying, whether legally or illegally, then price changes could have weak or even counterintuitive effects.

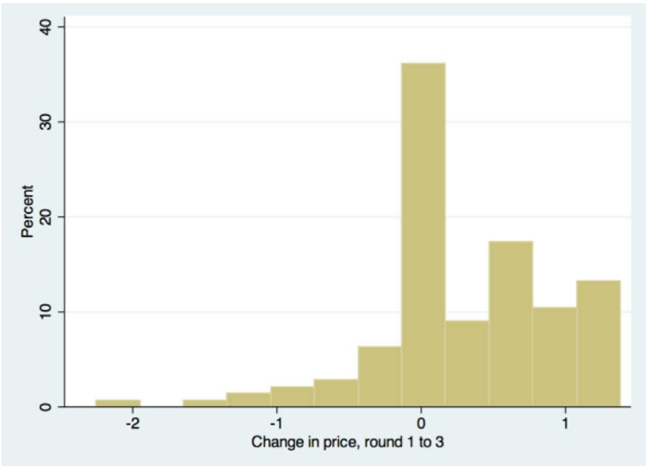

Fig. 2. Changes in meter rates from round 1 (spring 2011) to round 3 (spring 2012), in dollars.

Table 3
Mean changes in dependent variables between spring 2011 (round 1) and spring 2012 (round 2), distinguishing blocks with price decreases and increases.

	Total	Positive price change	Negative price change	No price change
Average occupancy (percent of time occupied by parked vehicles)	0.033	0.001	0.135	0.040
Parking availability (percent of time at least one space was available)	−0.024	−0.015	−0.008	−0.046
Duration per vehicle (min)	5.04	7.87	8.27	0.245
Hourly turnover per space (vehicles)	−0.065	−0.101	−0.065	−0.017
Occupants per vehicle	−0.052	−0.059	−0.005	−0.065
Double parking (incidents per hour)	−0.384	−0.367	−0.033	−0.545
Share of minutes unpaid	−0.030	0.004	−0.073	−0.060
Share of minutes illegally unpaid	−0.004	0.002	−0.016	−0.010
Share of minutes by disabled placards	−0.039	−0.055	−0.030	−0.027

N (Positive) ¼ 69 or 72.
N (Negative) ¼ 20.
N (No change) ¼ 51.

4. Data description

We observed 49 blocks (with 143 timebands) in both spring 2011 and spring 2012, as well as a roughly equivalent set observed in fall/winter 2011e2012. The average price change for the non-control blocks in our sample from spring 2011 to spring 2012 was larger than the SFpark average, and was an increase rather than a decreasedreflecting our decision to sample blocks where we anticipated price changes. The median and mean price changes between spring 2011 (round 1) and spring 2012 (round 3) were $0.25 and $0.31 respectively. There was a wide distribution of price increases and decreases (Fig. 2, below), since over the course of the year some blocks changed prices many times while others changed only a few times and still others not at all. The cumulative price change varied from a reduction of $2.25 per h to an increase of $1.25 per h, with an average increase in the morning of three cents, an average increase in the midday of 49 cents, and an average afternoon/evening increase of 43 cents. Prices rose an average of 10% on our blocks between May/June 2011 and May/June 2012, in contrast to the citywide average reduction of about 1% reported by Pierce and Shoup from August 2011 to May 2012.

On average, and in apparent contradiction to SFpark's goals, our sample blocks showed a trend toward more parking use and less parking availability as average prices increased (Table 3, column 1, below). Although the average price increased, the duration of the average parking spell on these blocks *rose* by almost 5 min (an increase of about 8%), while average hourly turnover per space *fell* almost 7%. As a result, average block-face occupancy rose an average of about 3%, and the minimum vacancy ratedthe share of time in which at least one space was available on the blockdfell about 2.4%.

This secular trend may have a number of explanations. If economic conditions improved during this time, for example, then drivers' increased willingness to travel and pay for parking might have swamped any effect from rising prices. Similarly, if drivers were slow to realize the city had removed time limits and installed more payment options, parking spells could increase over the course of the year even as prices rose. Were prices perfectly responsive to demand, they would incorporate such outside conditions, but as we have discussed, the SFMTA regulated both the magnitude and frequency of SFpark's price changes.

It is also possible that price increases and decreases influence parking behavior differently. Perhaps falling prices increase occupancy more than rising prices decrease it. To help account for this possibility, we distinguish blocks with price increases and decreases from those where prices remained unchanged (Table 3, columns 2e4). About half of our block-timebands saw price increases between the first and third round of our observations, while 20 saw price decreases. Fifty-one block-timebands had no price changes (25 of these timebands are from control blocks, which do not change in price). Block occupancy increased most in places where prices fell, and hardly changed where prices rose. This result aligns with the goals of SFparkdprice changes were associated with occupancy moving in the desired direction. However, in examining parking availability, we see a different pattern: average availability not only fell slightly in block-timebands where prices dropped, but also fell slightly in block-timebands where prices *rose*, and fell most on blocks where prices did not change. Meanwhile, the average duration increased *more* on block-timebands with price increases. Vehicle occupancy also fell, although it fell less on block-timebands where prices rose. Finally, the share of unpaid time remained largely unchanged on blocks where prices increased, and on other blocks fell.

5. Data analysis: methods

The descriptive statistics above suggest that average occupancydour metric that is closest to the one SFpark uses to adjust meter ratesdmay indeed change with prices in a way that improves parking availability. But the other measures did not appear to respond in the positive direction. In this section we present regressions that examine the effects of price changes in a more controlled fashion. We initially carried out cross-sectional regressions, which yielded strong positive associations between prices and average occupancy, and negative associations between prices and parking availability. We do not show these regressions because they are difficult to interpret and potentially misleading, for two reasons.[3] First, while meter rates in round 1 were quite similar to each other and thus did not reflect local demand, after round 1 the SFMTA changed rates based on the prior period's average occupancy. As a result, one could interpret any cross-sectional coefficients in two ways: as evidence of higher prices leading to more occupancy, or more occupancy leading to higher prices. Second, blocks vary along many criteria we cannot observe, such as demand for local retail and the availability of off-street parking. Such unobserved heterogeneity may confound cross-sectional analysis.

We therefore carried out regressions that take advantage of our repeated observations, by examining changes on the same blocks over time. This repeated-observations approach lets us control for any reverse causality between high prices and high demand; for general trends across all blocks (such as better economic conditions) that would influence occupancy and longer duration; and for any unobserved block-level heterogeneity that does not vary over

[3] The results are available upon request.

the 2011–2012 period (e.g., the presence of popular retail outlets or off-street parking on some blocks but not others).

In every regression the unit of analysis was the block-timeband, because that is the unit at which SFpark makes price changes. In each model we regressed the change in average occupancy, minimum vacancy, or another dependent variable upon the change in price and a set of control variables. We corrected for block-level clustering of timebands by using robust standard errors, and we also controlled for the initial price level. Because drivers may have responded to initial price changes differently from later changes, we separately examined changes between round 1 and 2 (spring–fall), between round 2 and 3 (fall–spring), and between round 1 and 3 (spring–spring).

Our first specification was as follows (equation (a), below):

$$\Delta y_{jk} = \alpha + \beta_1 P_{jk} + \beta_2 \Delta P_{jk} + \beta_3 C + \beta_4 \mathrm{Fin} + \beta_5 \mathrm{Mis} + \beta_6 \mathrm{SOMA} + \beta_7 \mathrm{Emp} + \beta_8 \Delta S + \varepsilon i; \tag{a}$$

where Δy_{jk} is the change in average occupancy, parking availability, or other dependent variable from round j to round k; P_j is the beginning meter price; ΔP_{jk} is the change in price from round j to round k; C is a dummy variable indicating if the block was a control (located outside a charging zone); and Fin, Mis, and SOMA are dummy variables representing fixed effects for the SFpark neighborhoods: Mission Street, the Financial District, and South of Market, with Civic Center as the reference category. Emp is total employment in the proximate block from the US Census's survey of Longitudinal Employer-Household Dynamics,[4] included as a static measure of demand that might affect both price and parking use. Finally, because the weather may affect parking demand, ΔS_{jk} is the change in the share of timeband hours with sunny and fair conditions as recorded by our surveyors.

We also tested whether responses to price increases were similar to responses to price reductions, by specifying a model in which coefficients were allowed to vary for price increases and decreases (equation (b), below). This was done by creating two price-change variables, one equaling the price change if positive and zero otherwise, and the other equaling the price change if negative and zero otherwise.

$$\Delta y = \alpha + \beta_1 P_1 + \beta_{2A} \Delta P_{jk_{\mathrm{POS}}} + \beta_{2B} \Delta P_{jk_{\mathrm{NEG}}} + \ldots + \varepsilon_i \tag{b}$$

Finally, because a common convention in price regressions is to take the natural log of the dependent and independent variables, we also estimated equations (c) and (d), below.

$$\ln y_k - \ln y_j = \alpha + \beta_1 \ln P_i + \beta_2 \left(\ln P_j - \ln P_k\right) + \ldots + \varepsilon i \tag{c}$$

$$\ln y_k - \ln y_j = \alpha + \beta_1 P_1 + \beta_{2A} \left(\ln P_j - \ln P_k\right)_{\mathrm{POS}} + \beta_{2B} \left(\ln P_j - \ln P_k\right)_{\mathrm{NEG}} + \ldots + \varepsilon_i \tag{d}$$

In sum, we had nine dependent variables and analyzed each one for three different time periods, in logged and unlogged forms, and with and without variables that distinguished price increases from price decreases. This approach results in many regressions, and for reasons of space we do not show all of them, but instead show some and discuss general trends across the others.

[4] We also explored the effect of employment in different industries (e.g., retail) but the price coefficients were not much affected.

6. Data analysis: results

A first point is that for the most part, the logged and unlogged results were consistent with each other. Thus we do not show or discuss the logged models, except in those cases where the results were sensitive to functional form. A second and more important point is that in many of our models the price-change coefficients were not statistically significant. In some specifications this is likely a result of sample size. In equations (b) and (d), where coefficients are allowed to vary for price decreases and price increases, the number of block-timebands in either the negative and positive categories is less than half of an already small sample. Thus an absence of statistical significance in these equations may not be substantively meaningful—although for the same reason, statistically significant coefficients in these models are telling. Some models also have less variance than others: the equations that examine only one round of price changes (round 1–2 or 2–3) capture fewer price changes than those analyzing the full year from round 1 to round 3. We consider these latter regressions, because they cover the longest period of time and largest price changes, to be most meaningful. We should also note that in this context an absence of statistical significance, if *not* driven by small sample sizes or low variance, can still be a substantive finding: it implies, counter to expectations, that price changes are having no discernible effect.

Starting with the measure closest to that used by SFpark itself, we find that average block occupancy per timeband decreased as prices increased, which is according to expectation. Between round 1 and round 2, an increase of $1 per h was associated with a roughly 20% decrease in occupancy (Table 4, model 1), although when distinguishing between price increases and decreases, only the decreases were statistically significant (model 2). However, between rounds 2 and 3, only one of the four models showed statistical significance, and that model yielded a positive price elasticity, implying that average occupancy *increased* on blocks with price increases (model 3). Over the full year-long period—again, the most statistically reliable interval—the results unambiguously suggest that rising prices are associated with lower occupancy, with negative and statistically significant coefficients in all equations (a)–(d). We show only one of these regressions (Table 4, model 4), with positive and negative price-change coefficients of −0.103 and −0.0699 respectively. These results imply that increasing the rate by $1 per h yields a reduction in occupancy of about 10%, while reducing the rate by $1 increases occupancy by about 7%.

However, the results for minimum vacancy—a better metric of parking availability—are not so promising. Between round 1 round 2, a dollar increase in price was associated with a 17.5% increase in parking availability (Table 4, model 5), although the model distinguishing price increases and decreases found no significant relationships. But between round 2 and round 3, we found statistically significant and negative relationships between price changes and the vacancy rate using all four model specifications (a)–(d). We show the results from equation (b), which suggest that a $1 m rate increase yields a 15.6% *decrease* in parking availability (Table 4, model 6). Over the full year-long period, there was no statistically significant relationship in equations (a)–(d) between price increases and changes in parking availability. In equation (b), blocks with price decreases had an *increase* in the share of time when at least one space was available (Table 4, model 7). Thus despite an unambiguous and intuitive relationship between price changes and average occupancy changes over the full year-long period, there is essentially no relationship over the same period between price increases and parking availability.

Average occupancy and parking availability are potentially influenced by many factors, including how long people park, how

Table 4
Changes in average occupancy and parking availability as a function of price change.

	(1)	(2)	(3)	(4)	(5)	(6)	(7)
	Average occupancy				Parking availability		
	1e2	1e2	2e3	1e3	1e2	2e3	1e3
Initial Price	−0.0192 (−0.74)	−0.0160 (−0.61)	−0.250** (−2.44)	0.0332 (0.57)	−0.0196 (−0.48)	0.0695 (1.27)	0.000892 (0.01)
Price Change	−0.199*** (−3.77)				0.175* (1.90)		
Positive Price Change		−0.123 (−1.57)	0.302* (1.95)	−0.103** (−2.07)		−0.156* (−1.91)	0.0471 (0.87)
Negative Price Change		−0.314** (−3.13)	−0.0220 (−0.56)	−0.0699* (−1.89)		−0.119** (−2.26)	−0.0846* (−1.91)
Control	−0.103** (−2.73)	−0.0917** (−2.38)	0.139** (2.96)	−0.0565 (−1.15)	0.0921 (1.47)	−0.174** (−2.19)	0.0299 (0.32)
Financial	0.0297 (0.68)	0.0343 (0.78)	0.00528 (0.11)	−0.0255 (−0.49)	−0.102 (−1.40)	0.196** (2.12)	0.124 (1.36)
Mission	−0.0172 (−0.61)	−0.0154 (−0.55)	0.0128 (0.18)	0.0742 (0.66)	0.0360 (0.76)	−0.0000535 (−0.00)	0.0229 (0.25)
SOMA	−0.0303 (−0.50)	−0.0257 (−0.42)	0.135** (2.05)	−0.00393 (−0.05)	0.0928 (1.24)	−0.152 (−1.60)	−0.0191 (−0.12)
Employment in block	−0.00000210 (−0.32)	−0.00000503 (−0.68)	0.0000154* (1.70)	0.00000285 (0.25)	0.0000294** (2.44)	−0.0000394** (−2.95)	−0.00000579 (−0.30)
Change in % of time sunny	−0.0129 (−0.54)	−0.0126 (−0.52)	−0.0100 (−0.36)	0.0472 (0.86)	−0.0361 (−0.79)	−0.0773* (−1.85)	−0.0450 (−0.77)
Constant	0.125** (2.75)	0.112** (2.59)	0.148 (1.13)	−0.0662 (−0.28)	−0.0962 (−0.98)	0.00527 (0.03)	−0.0350 (−0.21)
Observations	132	132	130	127	132	132	127
R-Squared	0.190	0.199	0.172	0.128	0.104	0.184	0.054

t statistics in parentheses; $*p < 0.10$, $**p < 0.05$, $***p < 0.001$.
Shading: logs of price, price change, and percent occupancy.
Included but not shown: Missing employment information in the proximate block (indicator variable).

many people park, and the number of occupants per vehicle. We turned next to an investigation of these factors to determine whether the parking dynamics on these blocks is explained by them, and we found that these metrics did not move in the expected or hoped-for direction either. The average duration of parking spells, for example, had a similar relationship to price changes as did parking availability. Over the first six months, price increases were associated with shorter parking durations (Table 5, model 8), while over the second six months the reverse was truedprice increases were associated with *increases* in average duration (model 9). The net result over the full year-long period was that price increases had no discernible effect on average duration, though one of the four models shows one significant and counterintuitive positive coefficient, implying a decrease in duration for blocks with price *reductions* (model 10). As for average hourly vehicle turnover per parking space, in logelog models it *decreased* with respect to price increases on average (model 11), though this appears to be driven by an increase in turnover on blocks where prices fell (model 12). Other turnover models did not have statistically significant results. None of our models examining carpooling yielded statistically significant results (these models are not shown).

If price increases create vacancy, we might expect double parking to decline as prices rise, assuming people double park because they cannot find a space. While no relationship between price changes and double parking is found for either six-month period by itself, double parking did fall on blocks with price increases over the full year-long period (Table 5, model 13).

The failure of parking availability, duration, turnover, and carpooling to respond to price changes in the expected way could be a function of the share of parkers who did not pay for their time and therefore are not affected by price changes. Of all parked minutes, the share that was unpaid averaged between 36 and 43% depending on the observation round. To determine whether prices affected non-payment, we carried out regressions similar to the ones presented above. We looked first at overall non-payment but found statistically significant relationships in only one model: between rounds 2 and 3, price reductions were associated with an increase in the share of time not paid, a counterintuitive result that would not explain the relationships we uncovered earlier (Table 6, model 14). However, when we specifically examined *illegal* non-paymentdthe share of people who failed to pay and did not have permits allowing them to park freedwe found statistically significant relationships with price changes. Between rounds 1 and 2, the association between price increases and illegal non-payment was substantial, perhaps reflecting an adjustment period to new prices or new meters in which users elected not to pay, and perhaps prior to any increases in enforcement (Table 6, model 15). Over the second six-month period, the relationship was smaller (model 16) and statistically insignificant with respect to price increases (model 17). The net result over the full year is a relatively small association between price change and illegal non-payment (model 18). Finally, we found no statistically significant relationship between price changes and changes in the share of vehicles using disabled placards (these results are not shown). Non-payment, in sum, does relatively little to illuminate our other results.

7. Discussion and conclusions

Over SFpark's first year, price increases on the blocks we examined were associated with reductions in average block occupancy. In this respect the program worked as intended. Yet these moves toward lower average occupancy did not appear to yield SFpark's desired policy outcome. The price increases that improved average occupancy did not consistently improve parking

Table 5
Duration, turnover, and double parking changes as a function of price changes.

	(8)	(9)	(10)	(11)	(12)	(13)
	Average duration per vehicle (min)			Average hourly turnover per space		Double parking
	1e2	2e3	1e3	1e3	1e3	1e3
Initial Price	3.691 (0.74)	−0.111 (−0.53)	−3.296 (−0.68)	0.0315 (0.12)	0.0346 (0.14)	1.222** (2.53)
Price Change				−0.344** (−2.25)		
Positive Price Change	−25.53* (−1.90)	0.674* (1.92)	−0.550 (−0.11)		0.0519 (0.19)	−0.445* (−1.72)
Negative Price Change	−14.88 (−0.44)	−0.191* (−1.90)	9.888** (2.30)		−0.486*** (−3.55)	−0.374 (−1.34)
Control	−18.14** (−3.45)	0.201** (2.17)	−15.49*** (−3.54)	0.192* (1.82)	0.258** (2.43)	−1.381 (−1.65)
Financial	−0.888 (−0.11)	−0.000617 (−0.00)	−6.434 (−0.90)	0.0550 (0.38)	0.0542 (0.37)	−0.889** (−2.11)
Mission	−0.682 (−0.11)	−0.0139 (−0.09)	−6.721 (−0.75)	−0.0519 (−0.33)	−0.0537 (−0.36)	−0.820* (−1.70)
SOMA	−1.618 (−0.16)	0.115 (0.71)	8.826 (1.12)	−0.255 (−1.46)	−0.215 (−1.23)	−1.950* (−1.72)
Employment in block	−0.00131 (−0.88)	−0.0000211 (−0.71)	−0.00230 (−1.51)	0.0000467 (1.62)	0.0000448 (1.51)	−0.000217* (−1.69)
Change in % of time sunny	−4.170 (−1.01)	−0.0490 (−0.69)	−2.206 (−0.46)	−0.0179 (−0.19)	−0.0368 (−0.40)	−0.243 (−0.97)
Constant	3.155 (0.24)	0.180 (0.63)	31.23 (1.61)	−0.233 (−0.72)	−0.293 (−0.95)	−1.738* (−1.95)
Observations	132	130	125	125	125	127
R-Squared	0.092	0.115	0.174	0.210	0.221	0.310

t statistics in parentheses; *$p < 0.10$, **$p < 0.05$, ***$p < 0.001$.
Shading: logs of price, price change, and percent occupancy.
Included but not shown: Missing employment information for proximate block (indicator variable).

availability. Although in the first 6 months price increases were associated with increases in the share of time at least one space was available, this initial trend reversed over the second six months. Over the full year, price increases had no significant association with parking availability. Higher prices also did not appear to influence driver behavior in other ways we might expect if those prices were to reduce cruising. Higher prices did not consistently lead to shorter average parking spells, nor could we find a statistically significant relationship between price changes and carpooling, or price increases and vehicle turnover per space.

Why didn't price increases yield the results we might expect? Our regressions examining average duration, turnover, and vehicle occupancy suggest that the explanation is only partly that blocks with the highest demand also experienced the largest price increases. Illegal non-payment likely played a real albeit modest role. However, we can speculate about other factors.

SFpark did not follow the road pricing examples of London and Singapore. Instead of large and sudden increases in price, it made small price adjustments over time, with restrictions on both how fast and how high prices could rise. Any effects from these slow and subtle price adjustments may have been eclipsed as drivers realized the city had greatly relaxed or removed parking time limits and installed meters that allowed cash-free remote payment. Though the time limit and payment changes occurred prior to our first round of observations, drivers may not have adjusted to them immediately.

Thus in high-demand areas, prices that rose slowly after time constraints were relaxed may have changed the composition of parkers, rather than created more vacancy. Blocks with high parking demand may have large unobserved queues, and thus may be less sensitive to incremental increases in price (Ottosson, Chen, Wang, & Lin, 2013). Rather than "clearing the market," rising prices might simply have changed the clientele, and attracted drivers with a higher willingness to pay. Possibly this problem will be solved over time, as the price eventually catches up to demand. On the other hand, SFpark has a price ceiling, and by the end of our survey many busy blocks had already come within a dollar of the maximum. Because we cannot measure the queue on blocks with no vacancy, we cannot be certain that SFpark's highest allowed price will be high enough to improve availability.

If this scenario is correct, we can view the results as a lesson about the politics of pricing. If public agencies or elected officials are unwilling to let meter rates rise quickly (because doing so would be politically unpopular), then in high-demand areas they risk charging higher and higher prices without substantially improving the availability of parking. But it is precisely in high-

Table 6
Changes in non-payment and illegal non-payment as a function of change in price.

	(14)	(15)	(16)	(17)	(18)
	Share of time not paid		Share of time illegally not paid		
	2e3	1e2	2e3	2e3	1e3
Initial Price	0.00420 (0.06)	−0.0241 (−0.91)	−0.0751 (−1.27)	−0.0729 (−1.24)	−0.0802 (−1.55)
Price Change			0.0756* (1.90)		0.0332** (2.05)
Positive Price Change	0.136 (1.62)	0.191*** (4.22)		0.0302 (0.78)	
Negative Price Change	−0.361** (−2.03)	−0.152 (−1.36)		0.147** (2.60)	
Control	0.133 (1.56)	0.0487** (2.04)	0.0334 (0.60)	0.0132 (0.24)	0.0250 (0.56)
Financial	−0.0929 (−1.10)	−0.0344 (−0.97)	0.0270 (0.38)	0.0232 (0.32)	−0.0177 (−0.30)
Mission	−0.0526 (−0.49)	0.0147 (0.48)	−0.157 (−1.63)	−0.160 (−1.65)	−0.122 (−1.52)
SOMA	0.0116 (0.12)	0.0650 (1.43)	−0.0599 (−0.80)	−0.0689 (−0.91)	−0.0318 (−0.52)
Employment in block	−0.0000111 (−0.59)	−0.000000584 (−0.08)	−0.00000564 (−0.57)	−0.00000508 (−0.52)	−0.00000550 (−0.62)
Change in % of time sunny	−0.0432 (−1.09)	−0.0321* (−1.77)	0.00437 (0.16)	0.0123 (0.41)	0.00581 (0.19)
Constant	0.0291 (0.13)	0.0384 (0.60)	0.276 (1.38)	0.294 (1.45)	0.283 (1.56)
Observations	130	132	130	130	125
R-Squared	0.177	0.203	0.166	0.181	0.143

t statistics in parentheses; *$p < 0.10$, **$p < 0.05$, ***$p < 0.001$.
Included but not shown: Missing employment information for proximate block (indicator variable).

demand areas where drivers create parking search externalities. The real benefit of higher prices comes when they nudge vacancy from zero spaces to one or two, and thus reduce cruising. If cities are unwilling to let the price float on the blocks with the highest demand, then raising meter prices may not deliver the minimum vacancy necessary to deliver these benefits.

Our results also speak to the importance of the price-setting criterion. Prices in SFPark are based on average timeband block-level occupancy rates. But while average occupancy is certainly correlated with parking availability, the relationship is not perfect. A block whose average monthly occupancy is 85% might nevertheless go many hours with a vacancy rate of zero. Thus cities might consider targeting their prices to achieve a minimum vacancy rate if their goal is to reduce the additional congestion and vehicle mileage that result from cruising for parking. A minimum vacancy criterion could also reduce overall parking use, which might be welfare-improving since auto use is generally underpriced.

In theory, congestion-priced parking is quite similar to congestion-priced driving. The SFpark experience thus far suggests, however, that in practice market-priced parking might play out quite differently than congestion-priced driving, and there may be peril in implementing congestion pricing halfway. We should not be too surprised if SFparkda system of price-controlled congestion pricingdyields short-term results that depart from the conventional theory of pricing. That said, the pricing regime for SFpark could be difficult to change. No one benefits from market-priced street parking if the public, enraged at large jumps in meter rates, revolts and ends the program. But this leaves open the question of whether pricing interventions could lead to unexpected and undesired outcomesdand whether a variable pricing regime is preferable to the status quo, when implementation falls short of theory.

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Does TOD Need the T?

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Does TOD Need the T?

On the Importance of Factors Other Than Rail Access

Daniel G. Chatman

Problem, research strategy, and findings: Transit-oriented developments (TODs) often consist of new housing near rail stations. Channeling urban growth into such developments is intended in part to reduce the climate change, pollution, and congestion caused by driving. But new housing might be expected to attract more affuent households that drive more, and rail access might have smaller effects on auto ownership and use than housing tenure and size, parking availability, and the neighborhood and subregional built environments.

I surveyed households in northern New Jersey living within two miles of 10 rail stations about their housing age and type, access to off-street parking, work and non-work travel patterns, demographics, and reasons for choosing their neighborhoods. The survey data were geocoded and joined to on-street parking data from a feld survey, along with neighborhood and subregional built environment measures. I analyzed how these factors were correlated with automobile ownership and use as reported in the survey.

Auto ownership, commuting, and grocery trip frequency were substantially lower among households living in new housing near rail stations compared to those in new households farther away. But rail access does little to explain this fact. Housing type and tenure, local and subregional density, bus service, and particularly off- and on-street parking availability, play a much more important role.

Takeaway for practice: Transportation and land use planners should broaden their efforts to develop dense, mixed-use, low-parking housing beyond rail station areas. This could be both more infuential and less expensive than a development policy oriented around rail.

Keywords: transit-oriented development, rail transit, auto use, parking, sustainability

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Transit-oriented development (TOD) is a common urban planning strategy; in practice, it often means developing new housing near rail stations. The term TOD can refer to buildings near transit, clusters of buildings near transit, or larger areas of up to a half-mile radius around a rail stop that are high-density and mixed-use, with walk-accessible shopping, pedestrian amenities, lower parking supply, and physical designs that are thought to encourage households to walk, bicycle, and take transit instead of driving (e.g., Belzer & Autler, 2002; Calthorpe, 1993).

One of the main objectives of TOD policies is to reduce the regional and global environmental impacts of auto use. Pursuing environmental goals through TOD has two important premises: frst, that households occupying newly constructed housing units near rail stations drive less than those in older housing near rail or those living farther from rail; and second, that the proximity to rail, as opposed to other attributes of TOD, is a critical part of the equation. There are reasons to doubt these premises. New housing might attract more affuent residents who drive more than those living in older housing near rail. Higher development density, less parking, and the presence of more shops and services nearby could all induce households to drive less, with or without rail access.

While studies have long found that households living near rail stations have substantially higher rates of transit use, particularly rail ridership (see review in Cervero, Ferrell, & Murphy, 2002), there are fewer studies of whether those households also own and use personal vehicles less. A study of selected transit-oriented housing developments in California in 2003 found that 72% of survey respondents commuted in personal vehicles, lower than the Census rate for surrounding cities of 90% in 1999 (Lund, Cervero, & Willson, 2004). A study of 17 transit-oriented developments in four U.S. urban areas, using vehicle counters in driveways, found 44% fewer vehicle trips than the published rates in the Institute of Transportation Engineers manual (Arrington & Cervero, 2008). Because neither of these studies included a control group, the magnitude of the reported differences may not be generalizable. The nature of non-response to the TOD survey, the use of a different survey instrument, and the timing of the survey (a four-year difference) could all infuence the lower observed auto use in comparison to Census rates; and lower vehicle trip counts in comparison to the Institute of Transportation Engineers estimates could be partly because those estimates are infated (Shoup, 2005).

Well-controlled statistical studies about the impacts on auto travel of the built environment are relevant because they control for many of the factors that comprise TOD. However, compared to built environment factors like population density, there are relatively few studies that include rail or transit access. A recent meta-analysis of more than 200 studies in the built environment-travel literature found just six studies at the household or individual level that used vehicle distance traveled as a dependent variable along with distance to rail or bus as an independent variable (Ewing & Cervero, 2010). The average elasticity of vehicle use with respect to transit proximity was very small, at –0.05, and likely not statistically signifcant.

Some research has found that rail access has either little association or a positive relationship with auto ownership or use. A study of San Diego and the San Francisco Bay Area found that proximity to heavy rail was associated with higher vehicle miles traveled when controlling for a large set of neighborhood-level built environment features (Chatman, 2008), and a study of Manhattan and Hong Kong found that rail station ridership was positively associated with the auto ownership of households living nearby (Loo, Chen, & Chan, 2010). A study of 370 metropolitan areas in the United States using structural equation modeling found that rail access was only weakly associated with auto distance traveled per capita (Cervero & Murakami, 2010). A simulation model conducted for Austin (TX) estimated that there was very little change in travel mode associated with increasing the share of new development near rail stations, although projected vehicle mileage was lower because auto trip distances were shortened (Zhang, 2010).

A slightly larger set of studies has found that rail access is associated with lower auto use. A study of both commute mode and auto distance traveled using data from a subset of 114 U.S. metropolitan areas in the National Household Travel Survey found that rail access, bus access, and urban form were all associated with lower auto use (Bento, Cropper, Mobarak, & Vinha, 2005). Another study of National Household Travel Survey data at the national level, using structural equations, found that rail accessibility, measured in terms of walking distance, was associated with lower vehicle miles traveled, both directly, presumably by substituting for auto use, and indirectly, via an association with higher population density (Bailey, Mokhtarian, & Little, 2008). A study of travel diary data from New York City found that subway lines near home and work were correlated with lower auto use and more walking, while noting that subway lines might be a proxy for walkable neighborhoods (Salon, 2009). Two international studies also found the expected relationship. A study of Santiago de Chile found that distance to urban rail stations was associated with higher levels of auto commuting, primarily via a direct effect on mode choice rather than any strong effect on auto ownership (Zegras, 2010). A study of national data from Germany, focusing on licensed drivers owning cars, found that walking distance to transit was highly correlated with vehicle distance traveled (Vance & Hedel, 2007).

An important missing factor in all of the above studies is the availability of vehicle parking. Off- and on-street parking has been studied even less than rail access, largely because data are not readily available. A case study of two neighborhoods in New York City argued that differences among them in auto use were likely caused by parking availability and not by transit access, highway access, or demographics (Weinberger, Seaman, & Johnson, 2009). A Census tract level study of New York data from 1998 found that both transit accessibility and an imputed measure of off-street parking availability were positively associated with auto commuting to Manhattan (Weinberger, 2012). A recent New York study, using the same dataset, restricted to units for which Google observations of parking could be made, found that both subway distance and off-street parking supply were signifcant predictors of auto ownership (Guo, 2013). Studies of how auto use might be affected by on-street parking availability are even scarcer; one study shows that that street cleaning requirements in New York City are associated with more driving for households without off-street parking, and less driving for housing units with it (Guo & Xu, 2012).

Almost all of these studies have limited applicability to the research question here because they omit potentially important covariates of rail access. In addition to parking availability, these include neighborhood scale and subregional built environment measures, and the age and type of housing. Few of them test for the importance of being within walking distance of rail.

Study Design

I conducted a mail survey of households within a two-mile radius of 10 rail stations in New Jersey, some of them living in purpose-built TODs as well as those living in new and older housing nearby and farther away from rail. I selected two-mile radius areas, rather than sampling the entire state, in order to balance the need to control for spatially correlated infuences on auto use with the need to observe travel behavior near and far from rail stops. Since transit use tends to drop off signifcantly beyond a half mile from the nearest transit stop (e.g., Dill, 2003; Pushkarev & Zupan, 1977), and since TOD is defned as being within walking distance of rail, households outside walking distance serve as controls. Restricting the sample frame to 10 station areas made it possible to collect on-street parking data for many of the respondents. These consisted of on-foot observations of on-street parking supply and use for a quarter-mile airline radius around the 10 stations. The analysis dataset was constructed by merging household survey and on-street parking data, then joining to that dataset neighborhood and subregional spatial measures constructed near respondent households using secondary data sources in a geographical information system. Only households nearest the rail stations had observations of on-street parking supply. These data assembly stages are described briefy below; more details are available elsewhere (Chatman & DiPetrillo, 2010).

The stations selected were Morristown and South Orange on the Morris & Essex Line, Perth Amboy and South Amboy on the North Jersey Coast Line, Rahway and Trenton on the Northeast Corridor Line, Westfeld and Cranford on the Raritan Valley Line, and 2nd Street and Essex stations on the Hudson-Bergen Light Rail line (Figure 1). These stations provide excellent access to downtown Manhattan and can be characterized as a mix of light rail, heavy rail, and high-frequency commuter rail with very good transit accessibility. The two-mile-radius area around these 10 stations includes about 740,000 people, or about 9% of the population of New Jersey, with generally better transit access and higher population density than the remainder of the state.

I constructed a sample of 5,000 housing units, including 1,073 units in recently built or substantially renovated multifamily housing developments within walking distance of the stations. The remainder of the sample was drawn from a list of households based on U.S. postal service addresses in zip codes within two miles of the stations. This list was geocoded, and I randomly sampled 2,427 housing units within a quarter-mile airline distance from the stations and an additional 1,500 units between a quarter mile and two miles away.

The survey questionnaire focused on housing unit characteristics, on- and off-street parking, work and non-work travel, household characteristics, and residen- tial location criteria (see Chatman & DiPetrillo, 2010). The questionnaire was pretested, and revised, prior to felding from June 3 to August 26, 2009. Five recruit- ment mailings were sent: an invitation letter with ques-tionnaire, a reminder postcard, two subsequent letters with replacement questionnaires to non-respondents, and a fnal last chance contact letter, in a modifed version of the Dillman total design method mail survey protocol (Dillman, 1978; Dillman, Dillman, & Makela, 1984). In total, 1,143 completed surveys were received, for a re-sponse rate of 25.4%. See Table 1 for a summary of data from the survey.

On-street parking observations were recorded for blocks ftting at least 50% within a quarter-mile airline buffer of the stations. Blocks were equally divided among three trained student surveyors. Field workers observed on foot during the evening peak parking period, between 5 p.m. and 8:30 p.m., collecting data on the number of on-street spaces by type (marked and unmarked), whether the spaces were occupied, parking duration limitations, space type (including limitations for disabled use and other permit holders), time restrictions, street cleaning, and no-parking periods, for 6,237 parking spaces on 818 street segments. The parking data were collected a year prior to the household survey (the delay was due to an interruption in research funding). The parking observations were merged with a street segment map and later aggregated in a GIS to construct measures of overnight parking spaces per road mile for a quarter-mile radius around the homes of the 532 households living within a quarter-mile airline distance of the stations.

The population density in Census blocks within a quarter mile of each respondent's home was calculated from data on population and land area of the blocks from the 2000 Census, using GIS. Local retail and total employment density were similarly calculated using the Census Bureau's 2008 Longitudinal Employer-Household Dynamics dataset (U.S. Census Bureau, 2008). Data on grocery stores, using NAICS code 445110, were downloaded from referenceusa.com, geocoded at the address level, and aggregated to the quarter-mile radius around respondent homes. The density of bus stops within a mile of home was calculated using bus stop locations from NJ Transit provided as of 2010. Net-work distance to the Manhattan central business district (CBD), defned as the nearer of Grand Central Station or Penn Station, was calculated using a street fle and network

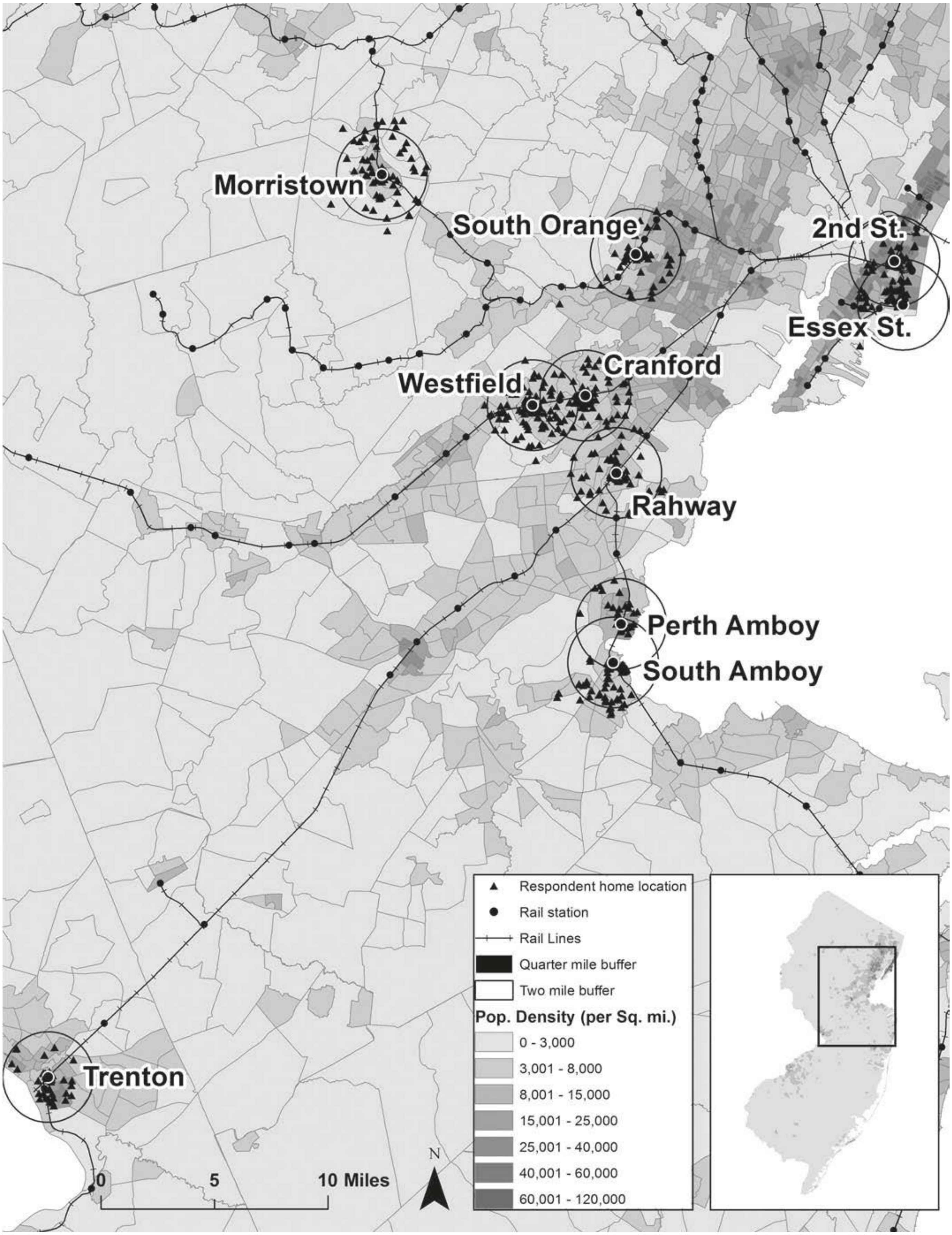

Figure 1. Selected stations with two-mile and quarter-mile buffers.

Table 1. Descriptive statistics (selected variables).

Variable	Obs	Mean	*SD*	Min	Max
Distance to nearest rail station (miles)	1,143	0.63	0.60	0.03	3.38
New housing near rail[a]	1,143	0.16	0.37		ind. var.
Older housing near rail	1,143	0.33	0.47		ind. var.
Older housing farther from rail	1,143	0.38	0.49		ind. var.
Less than one off-street parking space per adult in household	1,089	0.34	0.47		ind. var.
On-street overnight parking spaces (100s) per road mile within ¼ mile	532	1.67	0.67	0.42	3.02
Scarce on- and off-street parking[b]	508	0.15	0.36		ind. var.
On-street parking not observed	1,143	0.53	0.50		ind. var.
Duplex or triplex	1,143	0.08	0.27		ind. var.
Rowhouse or townhouse	1,143	0.08	0.27		ind. var.
Apartment or condominium	1,143	0.51	0.50		ind. var.
Other housing unit type	1,143	0.01	0.08		ind. var.
Missing housing unit information	1,143	0.01	0.08		ind. var.
Rental unit	1,143	0.37	0.48		ind. var.
Home owned without mortgage	1,143	0.13	0.34		ind. var.
Unknown unit tenure (owned or rented)	1,143	0.02	0.15		ind. var.
Population per square mile (000s) in Census blocks within ⅛ mile	1,133	12.6	12.2	0.13	87.6
Employment per square mile (000s) in Census blocks within ½ mile	1,143	8.5	14.7	0	89.6
Retail employment per square mile (000s) in Census blocks within ½ mile	1,143	0.5	0.5	0	4.8
Bus stops, 1-mile radius	1,143	103.7	118.7	0	622
Subregional employment density (000s per square mile in home PUMA)	1,143	4.1	5.5	0.40	19.6
Subregional bus stop density (10s per square mile in home PUMA)	1,143	3.8	6.0	0.31	23.7
Network distance to Manhattan CBD (miles, from home)	1,143	21.2	12.1	2.50	58.1
Household income ($10,000s, coded at category midpoints)	1,031	11.6	8.4	0.50	32.5
Household income not reported	1,143	0.10	0.30		ind. var.
Household size	1,141	2.3	1.3	1	9
Children in household	1,131	0.24	0.43		ind. var.
Single-parent household	1,131	0.03	0.17		ind. var.
Hispanic	1,143	0.14	0.34		ind. var.
African American	1,143	0.13	0.34		ind. var.
Asian American	1,143	0.06	0.24		ind. var.
Native American	1,143	0.01	0.10		ind. var.
Race not reported	1,143	0.04	0.19		ind. var.
Full-time worker	1,143	0.71	0.45		ind. var.
Part-time worker	1,143	0.07	0.26		ind. var.
Worker in management occupation	1,143	0.12	0.33		ind. var.
Worker in fnancial occupation	1,143	0.08	0.27		ind. var.
Worker in sales occupation	1,143	0.06	0.23		ind. var.
Worker in clerical occupation	1,143	0.04	0.20		ind. var.
Worker in craftsman occupation	1,143	0.02	0.15		ind. var.
Worker in laborer occupation	1,143	0.02	0.15		ind. var.
Worker in service occupation	1,143	0.05	0.21		ind. var.
Worker in unknown occupation (not reported)	1,143	0.02	0.14		ind. var.
Retired	1,143	0.17	0.38		ind. var.
Chose neighborhood based on access to friends/family	1,143	0.31	0.46		ind. var.
Chose neighborhood based on access to leisure opportunities	1,143	0.11	0.31		ind. var.
Chose neighborhood based on access to job	1,143	0.46	0.50		ind. var.
Chose neighborhood based on access to transit	1,143	0.42	0.49		ind. var.
Chose neighborhood based on access to children's schools	1,143	0.16	0.37		ind. var.
Chose neighborhood based on quality of public services	1,143	0.02	0.15		ind. var.
Chose neighborhood based on design	1,143	0.28	0.45		ind. var.
Chose neighborhood based on distance to school	1,143	0.05	0.23		ind. var.
Chose neighborhood based on distance to shops	1,143	0.18	0.39		ind. var.
Chose neighborhood based on distance to highway	1,143	0.09	0.29		ind. var.
Chose neighborhood based on house characteristics	1,143	0.22	0.41		ind. var.
Chose neighborhood based on other characteristics	1,143	0.15	0.36		ind. var.

Notes: ind.var. = indicator (0–1) variable.

a. New housing defned as seven or fewer years old at the time of the survey. Near rail is within walking distance, defned as 0.4 miles measured along the road network.

b. Scarce on- and off-street parking defned as having less than the median value for on-street parking space availability and less than one off-street parking space per adult in the household.

analysis routine in a GIS. Subregional measures of population density, employment density, and bus stop density were created with the 2005–2007 pooled American Community Survey Public Use Microdata Sample for the Public Use Microdata Areas (PUMAs) within which the households lived.

I constructed residential location criteria variables using answers to the question, "Please rate the top three factors that attracted you to this neighborhood." A dummy variable was set equal to 1 for any of a dozen such factors ranked by a respondent, regardless of rank value.

I set an indicator of off-street parking scarcity equal to 1 if the respondent reported having less than one off-street parking space per adult in the household, and 0 otherwise. I also constructed a variable representing the interaction between on- and off-street parking. If there is little off-street parking but ample on-street parking, or if there is plenty of off-street parking but no parking on the street, there should be no diffculty in parking a car. The variable was set equal to 1 if the household had less than one off-street parking space per adult and if on-street overnight parking availability was below the observed median value of 138 overnight parking spaces per road mile.

In the data description and analysis, I distinguish new from older units, and those within walking distance to rail from those farther away. New housing was defned as housing that had been built within seven years of the survey, based on respondent reports as well as independently collected information about selected buildings near the stations.[1] I defned walking distance as being within 0.4 miles of any rail station, as measured along the local street network, along which sidewalks were universally available in the study area. This is a bit shorter than Calthorpe's (1993) 2,000-foot defnition of walking distance for TODs. For most houses, it was roughly equivalent to a quarter-mile airline distance.

Table 1 shows means and standard deviations for the main variables used in the analysis.

Observed Differences by Rail Distance and Housing Age

Respondents living in new housing within walking distance of rail stations reported lower auto ownership, less auto commuting, and fewer weekly personal vehicle grocery trips than those living in new or older housing farther away (Table 2). They also had a lower rate of auto commuting and grocery trip frequency than those living in older housing near rail, a remarkable result given that this group also reported substantially higher household income.

A number of factors associated with proximity to rail and age of housing may play a role in infuencing auto ownership and use. Both rental housing and smaller housing units may attract households who use autos less because they are younger, of lower income, and have fewer children. In these areas, new housing near rail is much more likely to be for rent, and almost all consists of smaller units; in fact, even new housing farther from rail is much more likely to consist of smaller units (Table 3, columns 1 and 2). Off-street parking availability is lower in new housing near rail than in housing farther from rail, although newer units have more on-street parking available to them (Table 3, columns 3 and 4). Although a higher share of older housing near rail has combined low on- and off-street parking, the difference is not statistically signifcant (Table 3, column 5). The larger neighborhood spatial context could also play a role. Population density for both new housing and old housing near rail, and, notably, for older housing farther from rail, is much higher than for new housing farther from rail (Table 3, column 6). New housing near rail averages more than 150 bus stops within a mile, which is much higher than the other subgroups (Table 3, column 7).

There are other possible explanations for the observed lower auto ownership and use of residents of new housing

Table 2. Auto ownership and use by age of housing and distance to rail.

Subgroup[a]	Vehicles per household	Vehicles per adult	Commuted via SOV (indicator variable)	Grocery trips via auto, per week
New housing near rail	1.14 **	0.73 *	0.36 **	1.47 **
Older housing near rail	1.40 **	0.81 *	0.59	1.84 **
Older housing farther from rail	1.77	0.86 *	0.67	2.44
New housing farther from rail	1.67	0.96	0.63	2.45
Complete responses	1,118	1,118	810	878

Notes: SOV = singly occupied vehicle.

a. New housing is seven or fewer years old at the time of the survey. Near rail is within walking distance, defned as 0.4 miles measured along road network.

* Statistically signifcant difference from new housing farther from rail at the 95% level.

**Value is also signifcantly different from the value for the category below it, at the 95% level.

Table 3. Housing, parking, and spatial characteristics by age of housing and distance to rail.

	1	2	3	4	5	6	7
Subgroup[a]	Rental unit	Apartment/ condo/ townhouse/ rowhouse	Scarce off-street parking[b]	On-street parking per road mile	Low on- and off-street parking[c]	Population density (000s per square mile, ⅛-mile radius)	Bus stops (1-mile radius)
New housing near rail	0.57 **	0.98 **	0.47 *	193 **	0.12	13,200*	152**
Older housing near rail	0.48 **	0.62 **	0.39 **	152	0.17	12,800*	93
Older housing farther from rail	0.29 **	0.37 **	0.30 **	[183] *d	[0.07] d	13,400*	101 *
New housing farther from rail	0.16	0.71	0.19	[149] d	[0.25] d	7,810	79
Complete responses	1,116	1,135	1,089	532	508	1,143	1,143

Notes:

a. New housing defned as seven or fewer years old at the time of the survey. Near rail is within walking distance, defned as 0.4 miles measured along road network.

b. Off-street parking scarcity defned as less than one off street space per adult in the household.

c. Below median on-street parking + less than one off-street parking space per adult (see text).

d. Brackets denote very small subsample sizes. On-street parking data was gathered primarily for housing units within walking distance of rail.

*Statistically signifcant difference from new housing farther from rail at the 95% level.

**Value is also signifcantly different from the value for the category below it, at the 95% level.

near rail, but for these, data are harder to come by. For example, perhaps recent movers to TODs optimize their commutes around transit in the short run, but in later years as their work locations shift, they begin to drive. It is also possible that changing lifestyle preferences among younger people explain some of the correlation of new TOD housing and lower auto use, or that shifts in the housing and labor markets, and the recent economic downturn, are more keenly felt by those recent movers who are more likely to save money by owning and using autos less.

To investigate some of these potential explanations, I carried out a series of multivariate regressions for auto ownership, auto commuting, and auto grocery trip frequency.[2] For each of the three measures I frst carried out a regression with only rail proximity and age of housing. In the second regression I added other housing unit, parking, and spatial characteristics; in the third, I added demographic characteristics and residential choice criteria.[3] Different houses and neighborhoods may attract households with different levels of and preferences for auto ownership and use. The second model in each of the tables implicitly includes these residential choice effects, while the third model is meant to estimate effects independent of those choices. The variation in coeffcients denotes a range depending on how much of the effects associated with preferences and residential choice can be expected to occur in the future. The fourth model consists of a regression restricted to households within walking distance of a rail station, to test for the interaction of rail proximity and other factors such as parking availability. Finally, for auto commuting and grocery trip frequency, I carried out a ffth model including auto ownership as an (endogenous) explanatory variable, as explained below.

Auto Ownership

I defned per capita auto ownership as the number of reported vehicles divided by the number of adults in the household. In the frst model, per capita auto ownership was regressed on distance to rail and the housing age and walking distance threshold variables, using ordinary least squares. Each additional mile from a rail station is associated with an additional 0.09 vehicles per adult in the household (Table 4, column 1). Older housing, whether within walking distance of a rail station or farther away, is associated with fewer cars per capita (the omitted category is new housing outside walking distance). The coeffcients together suggest that new housing near rail is associated with 27% lower per capita auto ownership than new housing farther away.

The correlation of vehicle ownership with both rail proximity and housing age markedly decreased when housing, parking and built environment measures were controlled (Table 4, column 2). Neither rail proximity nor housing age is a statistically signifcant predictor of per capita auto ownership, and, in fact, the coeffcient on new housing near rail turns positive. Off-street parking scarcity, and low on- and off-street parking availability, are among the most powerful variables in this model. Houses with fewer than one off-street parking space per adult have

Table 4. Vehicles per adult in household as a function of distance to rail and other factors (OLS regressions).

	1	2	3	4
	Housing age and distance to rail	**Add housing, parking, and spatial variables**	**Add demo-graphics and preferences**	**Near-station households; same variables as Model 2**
Distance to rail (miles)	0.091 ***	–0.0034	–0.018	0.16
New housing near rail[a]	–0.18 ***	0.01	0.045	0.041
Older housing near rail	–0.11 **	–0.029	0.0017	
Older housing farther from rail	–0.14 ***	–0.048	–0.019	
Scarce off-street parking		–0.16 ***	–0.11 ***	–0.12 **
On-street overnight parking spaces		0.011	–0.0077	0.011
Scarce on- and off-street parking		–0.13 **	–0.11 *	–0.24 ***
Apartment/condo/row\townhouse		–0.065 *	–0.13 ***	–0.027
Unit type unknown		–0.35	–0.4 *	–0.23
Rental unit		–0.13 ***	–0.1 ***	–0.15 ***
Job density, ½ mile (000s)		–0.0023	–0.003 **	–0.0013
Bus stops, 1-mile radius		–0.0008 ***	–0.0007 **	–0.0004
Household income ($10,000s)			0.006 ***	
Owned home without mortage			0.074 *	
Household size			–0.065 ***	
Single-parent household			0.29 ***	
Hispanic			–0.075 **	
African American			–0.07 *	
Service occupation			0.16 ***	
Neighborhood choice: friends			0.055 **	
Neighborhood choice: leisure			0.1 **	
Neighborhood choice: access to job			0.051 *	
Neighborhood choice: near transit			–0.098 ***	
Neighborhood choice: public services			–0.2 **	
Neighborhood choice: looks/design			0.081 ***	
Neighborhood choice: near school			0.13 **	
Neighborhood choice: near highway			0.11 ***	
Constant	0.9 ***	1.11 ***	1.03 ***	1.23 ***
Observations	1118	1071	1063	525
Adjusted R^2	0.0245	0.1871	0.2776	0.1644

Notes: Included, statistically insignifcant, not shown: [Models 2–4] duplex/triplex, unit type missing, tenure unknown, population density (1⁄8 mile), retail employment density (½ mile), distance to Manhattan central business district, subregional bus stop density, subregional employment density; [Model 3] household income missing, children in household, Asian American, Native American, race unknown, occupation indicator variables (management, fnancial, sales, clerical, craft, labor, unknown), full-time worker, part-time worker, retired, neighborhood choice criteria indicator variables (school district, near shops/services, house characteristics, other).

a. New housing is seven or fewer years old at the time of the survey. Near rail is within walking distance, defned as 0.4 miles measured along road network.

* $p < .10$ ** $p < .05$ *** $p < .01$

0.16 fewer vehicles per adult, all else equal, while those with both low on- and off-street parking availability have an additional reduction of 0.13 vehicles per adult. Rental housing is also associated with 0.065 fewer vehicles per adult. Of the built environment variables, the most signifcant is the number of bus stops within a mile of the home. The coeffcient of –0.0008 implies that a one-standard-deviation increase in bus service (the equivalent of 118 bus stops in the mile radius around home) is associated with 0.09 fewer vehicles per adult.

The third model in this set adds in additional controls for demographics and preferences of households, accounting both for the fact that TODs may attract previous transit users as well as the fact that they may enable households moving in to use alternative modes more (Table 4, Model 3). A number of coeffcients on the newly entered demographic and preference variables are large and signifcant in this model, but I focus on the housing unit and spatial characteristics, as they are the most policy relevant. The distance from rail coeffcients remain insignifcant and small. The coeffcients on off-street parking scarcity and the combination of low on- and off-street parking are reduced from –0.16 to –0.11 and from –0.13 to –0.11 vehicles per adult respectively, but remain substantive, each representing a 13% reduction in auto ownership at the mean. The coeffcient on townhomes and apartments doubles, from -0.065 to -0.13; the increase appears to be due to household size being controlled, since larger households have fewer cars per adult. Townhomes and apartments might also have off-street parking that is farther from the unit. In short, this model suggests that sorting by income, household size, and housing preferences apparently does explain a signifcant share of the correlation of auto ownership with on- and off-street parking availability, the tenure and type of unit, bus access, and job density, but those measures remain signifcantly associated with lower auto ownership, in marked contrast to rail proximity.

Limiting the analysis to households near stations provides a test of how rail access may interact with other factors (Table 4, column 4). Low on- and off-street parking availability apparently has stronger effects combined with rail station proximity: there are 0.24 fewer vehicles per capita when the analysis is restricted to near-station households, almost double the relationship in Model 2.

Auto Commuting

Of the dataset of 1,134 respondents, 810 reported that they worked part or full time in the previous week, and of those, all reported their commute mode. A logit model of the decision to commute by auto (singly occupied vehicle) is presented in Table 5. Exponentiated coeffcients, or odds ratios, are shown; the increment greater or less than 1 can be interpreted as a percentage change in the probability of auto commuting.

Before controlling for non-rail factors, each mile from a rail station is associated with a 74% increase in the odds of commuting via auto, and households living in new housing within walking distance of a rail station are only 43% as likely to commute via auto compared to households in new housing farther away (Table 5, column 1). New and old housing are statistically indistinguishable from each other in this initial model.

When housing unit, parking availability, and built environment variables are introduced (Table 5, column 2), the effect on auto commuting of being within walking distance of rail vanishes entirely, while the continuous distance-to-rail coeffcient shrinks from 1.72 to 1.32 and becomes statistically insignifcant. Off-street parking, job density, subregional bus stop density, and distance to downtown are all highly associated with auto commuting. Households living in older housing are more likely to commute via car when controlling for housing, parking, and built environment factors. Since all households living in new housing have recently moved, those occupying older housing are perhaps more likely to have experienced changes in the location of work or other chained activity locations since their last move, and driving to work may have become a more attractive choice.

When controlling for demographic characteristics and residential location criteria, the positive association between older housing and auto commuting loses statistical signifcance, although it remains relatively large in magnitude (Table 5, column 3). Having scarce off-street parking remains very signifcantly associated with lower probability of commuting via auto, with the odds decreasing from 63% to 57%. Rail access becomes more insignifcant still.

The fourth auto commuting model is restricted to commuters within walking distance of rail to test for interactions between the presence of rail and other factors (Table 5, column 4). Households in new housing are less likely to commute via auto in this model, consistent with Model 2. While off-street parking is no longer independently signifcant, near-station households with both low on- and off-street parking commute by auto just 40% as much as other households. Few of the remaining variables in Model 2 are signifcant, with the exception of local population density.

Finally, I estimated an auto commuting model like Model 2 but with the addition of a single explanatory variable, the number of vehicles per adult. Since auto ownership is intimately tied to the commuting decision, adding it will tend to bias the coeffcient estimates for the other independent variables. But it does illustrate how parking supply, housing characteristics, and transit proximity are directly correlated with auto commuting and indirectly correlated via auto ownership. The number of vehicles per adult has an odds ratio of 7.59 while off-street parking loses statistical signifcance, suggesting that its effects on auto commuting are felt primarily via the auto ownership link (Table 5, column 5).

Table 5. Probability of commuting by singly occupied vehicle as a function of distance to rail and other factors (logit regressions).

	1	2	3	4	5
	Housing age and distance to rail	**Add housing, parking, and spatial variables**	**Add demographics and preferences**	**Near-station HHs only, same variables as Model 2**	**All HHs, add vehicles per adult to Model 2**
Distance to rail (miles)	1.74 ***	1.34	1.20	2.83	1.22
New housing near rail[a]	0.43 ***	1.00	1.00	0.61 *	1.02
Older housing near rail	1.06	1.68 *	1.41		1.83 *
Older housing farther from rail	1.00	1.79 **	1.61		1.93 **
Scarce off-street parking		0.63 **	0.57 **	0.85	0.83
On-street overnight parking spaces		1.30	1.10	1.13	1.51
Scarce on- and off-street parking		0.60	0.62	0.40 **	0.75
Tenure unknown		5.71 *	6.60 *	2.89	7.64 **
Population density, 1/8 mile (000s)		0.98 **	0.99	0.97 **	0.98
Job density, ½ mile (000s)		0.99 *	0.99 *	0.99	0.99
Subregional bus stop density (10s)		0.95 *	0.95 **	0.97	0.97
Distance to downtown (mile)		1.02 **	1.02	1.03	1.03 **
Household income > $25,000			2.43 *		
Race unknown			0.35 *		
Labor occupation			3.12 **		
Neighborhood choice: leisure			3.26 ***		
Neighborhood choice: access to job			2.06 ***		
Neighborhood choice: near transit			0.39 ***		
Neighborhood choice: school district			1.75 **		
Neighborhood choice: near school			2.70 **		
Neighborhood choice: near highway			1.96 **		
Neighborhood choice: other			1.68 *		
Vehicles per adult in household					7.59 ***
Observations	810	785	782	400	773
Pseudo R^2	0.0446	0.121	0.2239	0.1296	0.1805

Notes: Included, statistically insignifcant, not shown: [Models 2–5] on-street parking not observed, housing type dummy variables (duplex/triplex, apartment/condominium/rowhouse/townhouse, mobile home, other home, unit type unknown), rental unit, retail employment density (½-mile); [Model 3] household income, household income missing, owned home without mortage, household size, children in household, single-parent household, Hispanic, African American, Asian American, Native American, occupation dummy variables (management, fnancial, sales, clerical, craft, service, unknown), part-time worker, neighborhood choice criteria dummy variables (friends, public services, looks/design, house important).
a. New housing is seven or fewer years old at the time of the survey. Near rail is within walking distance, defned as 0.4 miles measured along road network.
Exponentiated coeffcients. * $p < .10$ ** $p < .05$ *** $p < .01$

Grocery Auto Trip Frequency

Rail access could directly and indirectly reduce driving to the grocery store by reducing auto ownership; by lowering the rate of auto commuting, and subsequent auto-based grocery trips chained into those commutes, or by encouraging the use of rail for the grocery trip itself. In the most recent National Household Transportation Survey, the category grocery/hardware/clothes shopping was the most common trip purpose, exceeding even commute trips in frequency (Federal Highway Administration, 2009). Grocery trips may be among the most routine because food is a basic necessity; they may, therefore, be relatively easily to remember and report accurately.

I constructed a measure of weekly auto-based grocery trip frequency using answers to a question about the timing and mode of the last three grocery trips, and dividing the weeks elapsed since the longest-ago reported grocery trip by the number of those trips that were conducted via a personal vehicle, either singly or jointly occupied. The variable was constructed only for the 878 respondents (77% of the pool) who reported full information on at least two grocery trips. I estimated these regressions using ordinary least squares. The variable is continuous, ranging from 0 (in about 5% of cases) to as high as 10.5 trips per week, with a mean of 2.07 trips per week.

The initial regression found an additional 0.51 auto-based grocery trips per week for every mile farther from a rail station, while new housing near rail has 0.73 fewer such trips than other new housing (Table 6, column 1). When controlling for parking supply, housing, and built environment characteristics, the signifcance of being within walking distance of rail and of housing age both disappear, although the distance-to-rail variable coeffcient remains statistically signifcant as it decreases in size (Table 6, column 2). Each additional grocery store within a quarter mile of home is associated with a reduction of

Table 6. Weekly auto grocery trips as a function of distance to rail and other factors (OLS regressions).

	1		2		3		4		5	
	Housing age and distance to rail		Add housing, parking, and spatial variables		Add demographics and preferences		Near-station HHs only; same variables as Model 2		All HHs, add vehicles per adult to Model 2	
Distance to rail (miles)	0.51	***	0.33	***	0.28	**	0.6		0.33	***
New housing near rail[a]	–0.73	***	–0.011		–0.065		0.053		–0.059	
Older housing near rail	–0.39	**	–0.099		–0.25				–0.081	
Older housing farther from rail	–0.22		–0.14		–0.22				–0.13	
Scarce off-street parking			0.2		0.13		0.16		0.22	
On-street overnight parking spaces			–0.14		–0.16		–0.094		–0.14	
Scarce on- and off-street parking			–0.57	**	–0.48	*	–0.6	**	–0.45	*
On-street parking not observed			0.08		0.04		–0.14		0.11	
Grocery stores, 1/4 mile			–0.098	***	–0.11	***	–0.14	***	–0.097	***
Bus stops, 1 mile radius			0.0023	**	0.0014		0.0001		0.0026	**
Job density, subregion (000s)			–0.07	**	–0.045		0.014		–0.068	**
Bus stop density, subregion (10s)			–0.077	***	–0.057	***	–0.068		–0.074	***
Distance to downtown (miles)			–0.034	***	–0.03	***	–0.013		–0.035	***
Household income ($10,000s)					–0.013	*				
Full-time worker					–0.41	**				
Neighborhood choice: school district					–0.31	*				
Vehicles per adult in household									0.4	***
Constant	2.09	***	3.42	***	3.99	***	2.84	***	2.98	***
Observations	878		855		851		428		843	
Adjusted R^2	0.0757		0.1614		0.1662		0.1342		0.1687	

Notes: Included, statistically insignifcant, not shown: Housing type dummy variables (duplex/triplex, apartment/condominium/rowhouse/townhouse, mobile home, other home, unit type unknown), housing tenure (rental unit, tenure unknown), population density (1/8 mile), employment density (½ mile), retail employment density (½ mile), household income missing, owned home without mortage, household size, children in household, single-parent household, Hispanic, African American, Asian American, Native American, race/ethnicity unknown, occupation dummy variables (management, fnancial, sales, clerical, craft, labor, service, unknown), part-time worker, retired, neighborhood choice criteria dummy variables (friends, leisure, access to job, near transit, public services, looks/design, near school, near shops/services, near highway, house important, other).

a. New housing is seven or fewer years old at the time of the survey. Near rail is within walking distance, defned as 0.4 miles measured along road network.

* $p < .10$ ** $p < .05$ *** $p < .01$

0.098 auto-based grocery trips per week. Low on- and off-street parking has a coeffcient of –0.57, implying a 25% reduction in auto-based grocery trips. Neither on-street nor off-street parking is independently signifcant, suggesting that for non-work trips requiring goods carrying, the auto is doubly attractive and only signifcant impediments to its use may have an infuence. Housing type and tenure, local population density, and local job density are not signifcant in these models, while subregional bus stop and employment density are negatively associated as expected. There are two puzzling coeffcients: distance from the Manhattan CBD is associated with fewer auto-based grocery trips, and the number of bus stops within a mile is associated with more (although this latter effect declines and becomes insignifcant once demographic characteristics are controlled). Perhaps there are more but also shorter auto trips in places that have high bus accessibility and are nearer to Manhattan. Trip distance is not measured in the dataset.

When demographic and residential location criteria variables are added, the implied effect of low on- and off-street parking remains large, at 0.48 fewer grocery trips per week, although it is now signifcant only at the 90% confdence level; the coeffcients on subregional bus stop density, the number of grocery stores, and distance to Manhattan are slightly smaller but still signifcant; and subregional employment density and bus stops within one mile are no longer signifcant (Table 6, column 3). Worker status is associated with 0.41 fewer trips to the grocery store, which could be caused by time scarcity relative to non-workers. Of all of the stated residential choice criteria, only seeking good schools is associated with grocery store trip frequency.

When restricting the sample to households near rail stations, the distance to rail variable becomes statistically insignifcant (Table 6, Model 4), suggesting that whatever role distance to rail plays in the use of autos for groceries, it is indirect. Perhaps it is a proxy for road congestion, which is not observed. The coeffcient on low on- and off-street parking stays about the same as in Model 2 and the number of grocery stores nearby becomes again larger and more signifcant, while the subregional built environment measures are no longer signifcant.

Finally, when the number of vehicles per adult is added as an endogenous explanatory variable (Table 6, Model 5), each additional vehicle per adult in the household is associated with an additional 0.4 auto-based grocery trips per week, and the independent infuence of low on- and off-street parking declines a bit but remains large and statistically signifcant at the 90% level. In contrast to the auto commuting models, this result implies that on- and off-street parking availability may affect auto-based grocery trip frequency, even for people with high auto ownership.

Conclusions

Developing high-density, mixed-use housing near rail stations may reduce regional road congestion and auto pollution while slowing the growth in greenhouse gas emissions caused by auto use. But those benefts may not depend very much on rail access. In these data, the lower auto ownership and use in TODs is not from the T (transit), or at least, not from the R (rail), but from lower on- and off-street parking availability; better bus service; smaller and rental housing; more jobs, residents, and stores within walking distance; proximity to downtown; and higher subregional employment density.

Previous disaggregate studies testing the infuence of rail access on auto ownership and use have typically controlled for only a subset of neighborhood or subregional built environment measures, rarely included housing type and tenure, and even more rarely controlled for on- or off-street parking supply. As others have argued, rail access and population density could be highly correlated with auto use due to unobserved variables like parking availability and walkability (e.g., Salon, 2009).

In contrast to the results here, a study of 1998 survey data from New York matched to current Google observations of off-street parking found that walking distance to subway stations in New York remained signifcant in predicting auto ownership when off-street parking was controlled (Guo, 2013). The analysis did not control for distance to downtown, subregional job and employment density, bus access, tenure and type of housing, or on-street parking availability; nor did it specifcally test the walking-distance thresholds included here. The study area could also play a role. Subway access in New York City is highly correlated with more generalized transit accessibility.

The comparatively weak infuence of rail access found in the present study is all the more remarkable given that New Jersey is so well served by rail and the share of rail commuting is so high. Although rail service undoubtedly attracts auto users in a way that buses do not, in some contexts it may also siphon off bus riders, walkers, and bikers. To test this hypothesis in the case of the commute to work, I estimated some additional commute mode regressions using binomial logit, like those presented in Table 5. Controlling for other factors, rail station distance was highly positively correlated with rail commuting, but negatively correlated with buses, walking and biking, ferry use, and working at home.[4] The apparent substitution between rail and other non-auto modes helps to explain why auto use varies relatively little as a function of distance to rail.

Some rail stations are located far from job and shopping clusters, and regional-level accessibility and distance to downtown are often shown to be more highly associated with travel patterns than are neighborhood characteristics (see Boarnet, 2011; Ewing & Cervero, 2010; Handy, 1993). Thus, some housing developments near rail might lead to unintended increases in auto use. This implies a continuing need for an explicit accounting of scale in specifying measures of the built environment to account for local, subregional, and regional measures (Chatman, 2008; Zhang & Kukadia, 2005).

The relationships among travel patterns, rail access, parking availability, and built environment measures are more complex than represented here. It is possible, for example, that rail investments could have played some role in either a market or political sense in increasing population density (cf. Bailey et al., 2008), increasing the number of grocery stores, and decreasing the amount of parking provided. But these results suggest rail plays at most an indirect role, and likely not a strong one, since the direct measure of rail is insignifcant in all of the controlled models.

Policy Implications

Current sustainability policies are often quite focused on investing in rail and developing housing near rail stations. For example, California Senate Bill 375, a widely observed and admired attempt to incorporate climate planning within regional transportation and land use planning, gives special consideration to transit priority projects: dense housing development within a half mile of a major transit station or high-quality transit corridor (Cal. Govt. Code §21155.1). Such a focus primarily on TODs to reduce greenhouse gases could miss the boat. These results suggest that a better strategy in many urban areas would be to incentivize housing developments of smaller rental units with lower on- and off-street parking availability, in locations with better bus service and higher subregional employment density.

Rail station areas may be among the most likely to be targeted for housing development proposals because developers are aware that public opposition is often lower near rail stations and because policymakers and urban planners believe that rail access will mitigate traffc impacts. But such a policy will not serve long-term sustainability interests if, in fact, rail investments and rail-proximate housing make little difference in auto use in and of themselves. The focus on rail is particularly problematic in cases where developments near rail stations are simply transit adjacent, with high amounts of parking, low density, and large units being offered for sale.

Denser housing developments coupled with good management of automobile parking could reduce auto use in many contexts, and there could be a substantial market for it. Previous research has suggested the need to reduce parking requirements to take account of the fact that demand for parking is lower in places with transit service (e.g., Rowe, Bae, & Shen, 2011). But parking requirements likely themselves affect travel by oversupplying parking (Cutter & Franco, 2012); in other words, parking demand may be lower in places with rail service partly because parking is scarce. Public agencies are heavily involved both in regulating minimum amounts of off-street parking and in providing and regulating on-street parking. Developers could be allowed to provide less off-street parking, while on-street parking could be priced, managed, and permitted in order to mitigate spillover effects (Shoup, 2005). Future population growth in the United States may well be concentrated in cities, and on-street parking may become scarce while private off-street parking will become very expensive to construct. If so, existing policies regarding on- and off-street parking could signifcantly constrain densifcation and infll development.

It is fortunate if access to rail is not a primary factor in reducing auto use, not only because rail infrastructure is expensive, but also because the fraction of available land near rail stations is limited. That said, ubiquitous higher housing density and scarce on- and off-street parking could cause greater local auto congestion if not carefully managed. In fact, positive regional and global effects may result from those negative local impacts, if they quash more driving. However, negative local impacts induce cities to frown on dense development and neighbors to protest it. How can urban planners bring about a more widespread relaxation of parking regulations, height limits, foor-to-area ratio standards, and general plans that restrict the form and location of development and redevelopment? That is the planning puzzle that deserves our focused attention. The pursuit of rail-oriented development may be a distraction from it.

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Notes

1. Housing age was reported by survey respondents and supplemented with information about the year of development for known multifamily projects. Almost 20% of respondents reported that they did not know the age of the unit they were living in or did not answer the question; only 6% of those were in multifamily units known to be new. The remaining units are assumed to be at least eight years old.

2. Alternative methods such as structural equations, nested logit, or two-stage least squares could be used to control for the potential endogeneity of residential location, public transit, population density, parking, or other dependent variables (e.g., Bailey et al., 2008; Cervero & Murakami, 2010; Deka, 2002; Salon, 2009). Such efforts require plausibly exogenous instruments and historical data, which are not present in this dataset, but could be the subject of future research.

3. Multicollinearity generally did not present problems in these data, with the exception of the variable for on-street parking and, in the models restricted to near-station households, the subregional built environment variables. For example, for the 14 models presented here, the variance infation factor on distance to rail averaged 1.99 with a range of 1.72 to 2.29. When independent variables of interest were statistically insignifcant in the presence of variance infation, I removed other collinear variables to see if signifcance occurred once variance infation was reduced. Statistical signifcance was generally unaffected, except for the spatial variables; as a result the set of spatial variables varies slightly for each of the model sets, except that Models 4 and 5 in each set are kept consistent with Model 2.

4. The carpooling model does a poor job of explaining the likelihood of carpooling; distance to rail is not signifcant, nor are many of the other built environment variables. I ran other variants of this modal categorization but results were very similar. Detailed results are available upon request.

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