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MOVING LOS ANGELES

Short-Term Policy Options for Improving Transportation

Paul Sorensen • Martin Wachs • Endy Y. Min • Aaron Kofner • Liisa Ecola
Mark Hanson • Allison Yoh • Thomas Light • James Griffin

Sponsored by James A. Thomas, the L.A. County Metropolitan Transportation Authority,
the Music Center of Los Angeles County, and the RAND Corporation



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A RAND INFRASTRUCTURE, SAFETY, AND ENVIRONMENT PROGRAM

This study was sponsored by James A. Thomas, the L.A. County Metropolitan Transportation Authority, the Music Center of Los Angeles County, and the RAND Corporation and was conducted under the auspices of the Transportation, Space, and Technology (TST) Program within RAND Infrastructure, Safety, and Environment (ISE).

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Preface

The Los Angeles (L.A.) region, according to many studies, has the most severe traffic congestion in the United States. Longer-term trends in many of the underlying causal factors—including growth in the population, the economy, and the movement of goods through the Ports of Los Angeles and Long Beach—suggest that congestion will continue to worsen in the coming years, absent significant policy intervention. Excessive traffic congestion detracts from quality of life, is economically wasteful, is environmentally damaging, and exacerbates social-justice concerns. Finding efficient and equitable strategies for mitigating congestion will therefore serve many social goals.

The primary intent of this study was to recommend strategies for reducing congestion in L.A. County that could be implemented and produce significant improvements in a short time, defined as roughly five years or less. Specific elements of the study include the following:

- reviewing the academic literature for insights on congestion
- examining available data to characterize traffic congestion in Los Angeles, including current conditions and recent trends
- examining relevant transportation and land-use features in Los Angeles to diagnose the key contributors to congestion in the region
- identifying the range of available congestion-reduction strategies that could be implemented and produce effects in the near term
- assessing the strengths and weaknesses of each option with regard to cost/revenue implications, short- and longer-term effectiveness in reducing congestion, effects on other social goals, likely imple-

mentation obstacles, and the current level of implementation in Los Angeles

- recommending a smaller set of strategies that offers the greatest prospects for reducing congestion and improving transportation options in Los Angeles
- considering complementary strategies for building political consensus around effective, albeit potentially controversial, congestion-reduction measures.

The study was sponsored by a small consortium of public and private donors sharing an interest in reducing traffic congestion through improved transportation policy in Los Angeles, including James A. Thomas, the L.A. County Metropolitan Transportation Authority, the Music Center of Los Angeles County, and the RAND Corporation.

The intended audience includes community leaders and elected officials in L.A. County along with other interested residents in the region. Though the specific recommendations proffered in the book are tailored to the L.A. region, leaders in other cities who are interested in strategies to reduce congestion should also find the underlying analysis to be of value.

The RAND Transportation, Space, and Technology Program

This research was conducted under the auspices of the Transportation, Space, and Technology (TST) Program within RAND Infrastructure, Safety, and Environment (ISE). The mission of ISE is to improve the development, operation, use, and protection of society's essential physical assets and natural resources and to enhance the related social assets of safety and security of individuals in transit and in their workplaces and communities. The TST research portfolio encompasses policy areas including transportation systems, space exploration, information and telecommunication technologies, nano- and biotechnologies, and other aspects of science and technology policy.

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Summary

The time is right for aggressive transportation-policy reform in Los Angeles. Though rising fuel prices have reduced traffic on some routes in recent months, the broader trend is that traffic conditions on the region's highway and road network have steadily deteriorated over a period of many years. Frustrations with congestion remain high, and many residents and policymakers agree that "something must be done!" Traffic congestion is not merely annoying—it lowers quality of life, detracts from economic competitiveness, leads to additional traffic accidents, wastes fuel, produces excess greenhouse-gas emissions, exacerbates air-quality problems for communities in the vicinity of crowded freeways, and slows bus service for those who rely on transit. The buzz in print and on the Web implies an increased willingness to consider more innovative policies for solving the region's congestion problem.

Past debates about reducing congestion often revolved around how best to spend limited transportation dollars. Should the region invest in more buses or rail lines, add more left-turn lanes and signals, augment the traffic-signal timing and control system to reduce intersection delays, or widen freeway bottlenecks? While such investments may slow the rate at which congestion gets worse, they are fundamentally unable to halt or reverse the growth of congestion in the face of increasing automotive travel. Neither do the most commonly proposed land-use strategies offer much hope on their own.

A key finding from the RAND Corporation study described in this book is that strategies that rely on pricing to manage the *demand* for driving—e.g., by charging more for driving and parking during

peak hours in the most congested locations—are extremely effective in producing sustainable reductions in congestion. Pricing strategies lead to more-efficient use of existing road capacity and can raise substantial revenues to fund needed transportation improvements. Though certain forms of pricing may lead to concerns about the ability of lower-income drivers to pay the charges, the research suggests that investing the resulting revenue in much-improved transit services and other nonautomotive travel options can be effective in mitigating such concerns.

Policies that improve alternatives to driving alone (such as transit, carpooling, biking, or walking) can play an important role in improving transportation in Los Angeles, as can supply-management strategies designed to enhance the capacity and efficiency of existing streets and freeways. But one of the keys to long-term congestion relief will be an integrated package of reforms, and efforts to promote transportation alternatives and improve the existing road network will be much more effective if implemented in concert with strategies for managing the demand for peak-hour automotive travel through the proven mechanism of pricing. In fact, the research clearly demonstrates that any package of reforms that does not include pricing strategies will not achieve lasting reductions in traffic congestion. As a region, then, L.A.-area stakeholders must summon the political willpower to face a tough decision. Will Los Angeles begin to pursue pricing to manage demand for peak-hour automotive travel, or will it instead simply allow congestion to worsen in the coming decades? These are the only choices.

Strategies for Reducing Congestion in L.A. County and Recommendations That Can Be Implemented and Produce Results Quickly

The principal goal of the RAND study was to develop short-term congestion-reduction recommendations for application within L.A. County—that is, strategies that could be implemented and lead to marked reductions in peak-hour traffic delays within a period of approximately five years. We paid specific attention to strategies that

would prove helpful in dense urban areas, where congestion is often the most intense, though some of the strategies considered should also be useful in suburban locales. We constrained the focus to policy options applicable to passenger traffic; while some of the strategies might apply to truck traffic as well, we did not include strategies specifically targeted at goods movement.

These criteria, adopted to establish a logical and reasonable bound on the study's scope, precluded including certain potentially promising strategies that might be pursued in Los Angeles. The short-term nature of the recommendations, for instance, ruled out major capacity expansions, such as new freeway lanes or rail transit lines, which take far longer to plan, approve, fund, and build. It also removed from consideration major land-use policies related to zoning, parking, urban density, and transit-oriented development. Though such reforms could be implemented within five years, their effects would unfold much more slowly—over a period of decades—as land-use patterns evolve with successive waves of redevelopment. As another example, given the decision to focus on passenger- rather than freight-oriented strategies, we did not consider the provision of grade separations at rail crossings, though it could offer significant benefits in some parts of L.A. County.

Even with these scope limitations, however, there are still many viable options for reducing traffic congestion in the near term. Broadly, these include strategies for making more-efficient use of existing roadways, strategies for managing demand for peak-hour driving, and strategies for improving bus transit and other nonautomotive travel modes.

During the course of our study, we reviewed findings from the literature, examined available data, and spoke with agency staff and elected officials in the county. Our efforts were aimed at the following:

- understanding congestion at the conceptual level
- characterizing congestion in L.A. County
- diagnosing the severity of congestion in L.A. County
- identifying and evaluating short-term congestion-reduction strategies
- developing short-term congestion-reduction recommendations

- developing complementary recommendations to help overcome political obstacles and build the consensus necessary for implementation.

This document summarizes the study's findings related to congestion in general and to the most promising congestion-reduction strategies for jurisdictions operating within L.A. County in particular. Because congestion plagues many other metropolitan areas in the United States, the discussion in this book should be of interest to readers in other urban locales as well. The prime focus, however, is on Los Angeles (as a point of clarification, note that we often use the generic term *Los Angeles* in describing conditions applicable to the region as a whole; where greater jurisdictional specificity is required, we explicitly refer to either L.A. County or the City of Los Angeles).

The results of our analysis led to 13 integrated short-term recommendations for reducing traffic congestion on the network of arterial roads and highways in L.A. County. The recommendations feature several pricing strategies for managing peak-hour automotive travel and raising transportation revenue, along with complementary strategies for improving alternative transportation options and boosting the efficiency of the existing road network.

Among the recommendations, those involving the use of pricing are likely to stir the greatest debate. The book cites numerous real-world examples illustrating the success of existing pricing programs and outlines compelling theoretical arguments to show that pricing—by requiring that drivers consider the full social and environmental costs in their travel decisions—helps to promote greater social and economic welfare. Even so, there will be those who view themselves as worse off under a system of pricing, and there will also be those who oppose the idea on principle. With this in mind, we chose to consider complementary strategies for mitigating concerns and building political consensus as well.

Historically, in Los Angeles, when circumstances have indicated both the need and the opportunity for change, the business community has responded by galvanizing support for significant transportation reforms. Successful action on the congestion problem will now

require the collaboration of a much broader group of interested parties who can initiate and sustain forward momentum and ensure that the concerns of all affected groups are considered. Though the transportation-policy recommendations developed in this book would be implemented by public agencies, the complementary strategies for building political support are intended to assist community leaders who would like to play a role in promoting meaningful efforts to reduce traffic congestion and improve transportation options in Los Angeles.

What Do We Know About Congestion?

In considering congestion-reduction strategies for Los Angeles, we found it helpful to first take stock of accumulated wisdom based on the prior work of transportation researchers and scholars. The following points highlight several key insights.

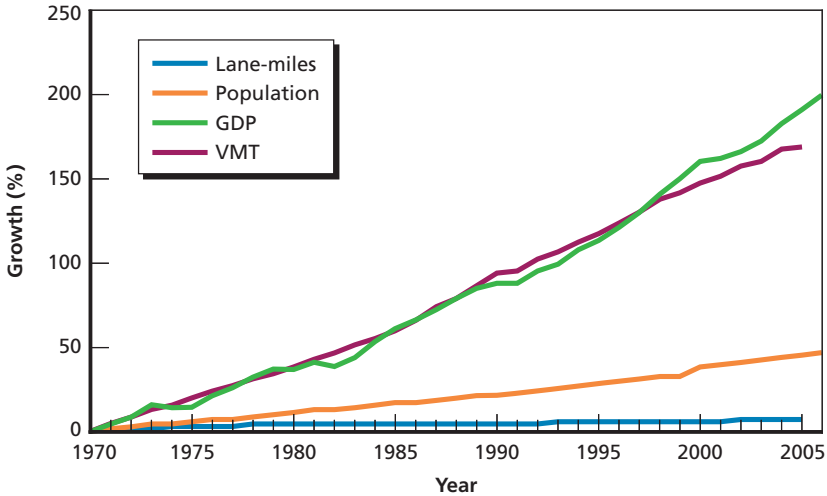
Congestion Results from an Imbalance Between the Supply of Road Capacity and the Demand for Driving During Peak Travel Hours

Potential solutions thus include managing peak-hour demand and boosting supply. Until supply and demand are brought into closer alignment, however, congestion will resolve the imbalance by making drivers wait their turn to use the available road capacity.

Growth in Automotive Travel Has Far Exceeded Road Expansion in Recent Decades

One of the reasons that demand outstrips supply is that the number of vehicle-miles traveled (VMT, a common measure of automotive travel) has been growing much more quickly than has the nation's road supply for many years now. This is shown in Figure S.1, which compares growth in road lane-miles, population, the economy (as measured by gross domestic product, or GDP), and VMT in the United States since 1970. During this period, the supply of lane-miles has been relatively stagnant, while growth in VMT has far exceeded growth in the population and, in fact, tracks quite closely with GDP. Assuming continuation in these underlying trends, the gap between VMT and

Figure S.1
Growth in Lane-Miles, Population, Gross Domestic Product, and Vehicle-Miles Traveled in the United States Since 1970



SOURCES: California Department of Industrial Relations (2007); Caltrans (undated, 2008).

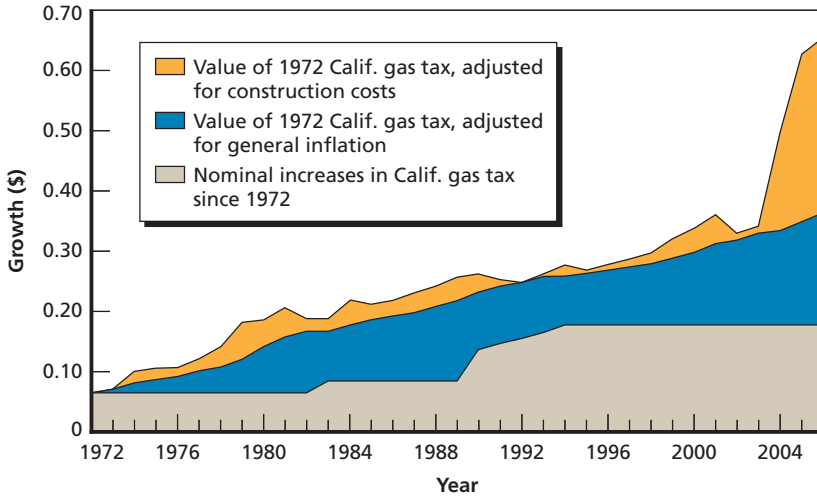
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road supply is likely to further widen in the coming years, leading to even more traffic congestion.

Transportation-Revenue Shortfalls Preclude Los Angeles from Building Its Way Out of Congestion

Federal and state motor-fuel excise taxes, responsible for a significant share of transportation funding, are levied on a cents-per-gallon basis and thus need to be raised periodically to offset the effects of inflation and improved fuel economy. Wary of antitax sentiments, legislators have become increasingly reluctant in recent years to address this politically unpopular task; in California, the gas tax was last raised in 1994, while the last increase in the federal gas tax occurred in 1993. As a result, Los Angeles now collects far less real revenue per mile of vehicle travel than in years past. Consider Figure S.2, which shows growth in the nominal per-gallon excise gas tax in California compared with growth in inflation and the cost of construction since 1972.

Figure S.2
Growth in California Gas Tax, General Inflation, and Highway-Construction Costs



SOURCES: California Department of Industrial Relations (2007); Caltrans (undated, 2008).

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While the gas tax has been raised several times and now stands at \$0.18 per gallon, during the same period, the value of the \$0.07 gas tax in 1972 has risen to \$0.36 with inflation and to \$0.65 in terms of construction costs. Just to keep pace with inflation, then, the current California excise gas tax would need to be doubled; to keep pace with highway-construction costs, it would need to be more than tripled. In short, the gas tax no longer buys what it used to. Absent a significant boost in available transportation revenue, Los Angeles's ability to provide new road (or transit) infrastructure is severely limited.

Failure to Charge the Full Costs Associated with Automotive Travel Inflates the Demand for Driving

From an economic perspective, automotive travel is underpriced. Driving a vehicle creates environmental and social costs, such as harmful emissions and additional congestion delays for other travelers. When we choose to drive, we are not forced to pay for these so-called external costs; rather, they are passed along to other members of society,

such as drivers traveling in our traffic wake or residents living alongside the freeways on which we travel. Because driving is underpriced, society tends to overconsume road space; that is, we make many trips for which the total costs (including external costs passed on to others) exceed the total benefits. In theoretical terms, this reduces social welfare. In practical terms, it leads to greater traffic congestion and contributes to environmental problems, such as poor air quality and additional greenhouse-gas emissions.

Small Changes in Driving Can Lead to Large Changes in Congestion

The relationship between the number of vehicles and their travel speed can be described as *nonlinear*. When there are just a few cars on the road, more can be added without having much effect on travel speed. When the road is already crowded, on the other hand, adding just a few more cars can trigger congestion, significantly reducing travel speed and simultaneously diminishing the road's effective capacity (that is, reducing the number of vehicles per lane per hour that the road can carry). The practical import of this observation is that when a road is already congested, reducing the number of cars trying to use that road at the same time by even a small amount can often produce much larger reductions in congestion delays. For example, reducing the number of cars on the road by 2 or 3 percent might cut congestion delays by 10 or 15 percent.

The Easy Solutions to Congestion Have Already Been Implemented

Congestion is not a new phenomenon, and the easy solutions—those that are effective, inexpensive, and uncontroversial—have long since been applied. Remaining options tend to be costly, controversial, or only moderately effective. This leaves Los Angeles with two options. It can either continue to implement a wide range of relatively inexpensive and uncontroversial measures that offer modest benefits in the hope that their combined effects will be significant, or it can strive to overcome financial and political obstacles and pursue the options that appear to hold the greatest promise.

Few Congestion-Reduction Strategies Remain Effective in the Longer Term

A phenomenon described as *triple convergence* (Downs, 2004) undermines the effectiveness of many congestion-reduction strategies. In short, when traffic conditions on a roadway are improved during peak hours, additional travelers will tend to converge on that newly freed capacity from (1) other times of travel, (2) other routes of travel, or (3) other modes of travel, slowly eroding the initial peak-hour congestion-reduction benefits in the busiest travel corridors. Longer-term increases in the demand for automotive travel resulting from population growth and economic expansion can further undermine a strategy's effectiveness. This is why we often see, for instance, that flow improves for a short while when new lanes are added to a freeway but usually returns to former levels of congestion within just a few years. This is not to suggest that such improvements lack merit; they may, for instance, afford a greater level of aggregate travel, improve travel choices, or reduce the spatial and temporal spread of congestion. Rather, the key point is that they will prove unable to reduce peak-hour congestion in the busiest corridors for more than a short period.

Only Pricing Strategies Can Produce Sustainable Reductions in Traffic Congestion

The only strategies resistant to the effects of triple convergence involve the use of pricing to manage the demand for peak-hour automotive travel (Downs, 2004). Often described as *congestion pricing*, examples include charging higher tolls to drive during peak hours or charging higher prices to park in the most convenient curb spaces at the busiest times of day. The main reason that the effectiveness of pricing strategies is not eroded by triple convergence is that the same peak-hour charges that encourage some to change their travel patterns also deter others from converging on the freed capacity. Another way of stating this is that pricing strategies represent the only approach that can reduce congestion without inducing additional automotive-travel demand. Pricing also remains effective in the longer term in the face of generally increasing demand, provided that the prices charged are allowed to rise with demand. Pricing strategies can help raise needed revenue as

well, and, by preventing congestion, they facilitate more-efficient use of existing capacity.

Is Congestion in Los Angeles Really So Bad?

Angelenos complain about traffic congestion, and rightly so. Some overseas cities, such as Bangkok, Jakarta, and Lagos, are more congested, but, by most measures, traffic conditions in Los Angeles are indeed worse than in any other major U.S. metropolitan area.

Since beginning this study in the summer of 2007, the economy has weakened and fuel prices have surged. Drivers have looked for ways to reduce their travel, and data from California's Freeway Performance Measurement System (PeMS) suggest that traffic delays have declined on some local freeways in the past six to nine months. Yet the economy will, at some point, recover, and consumers will increasingly switch to more fuel-efficient vehicles should gas prices remain high. As the population continues to grow and as goods continue to flow through the Ports of Los Angeles and Long Beach, traffic congestion will sooner or later begin to worsen once again.

This is a problem, as congestion in Los Angeles (even with recent declines) is already quite severe. According to the Texas Transportation Institute (TTI), which develops widely cited congestion statistics for large U.S. metropolitan areas (Schrank and Lomax, 2007), the greater L.A. metropolitan area (as defined by the U.S. Census Bureau) consistently leads the nation in the following:

- total annual hours of delay for all travelers (490 million)
- total annual gallons of wasted fuel for all travelers (384 million)
- average annual hours of delay per peak-period traveler (72 hours)
- average annual gallons of wasted fuel per peak-period traveler (57)
- total annual economic costs as a consequence of congestion delay (more than \$9 billion, up from \$2 billion in 1982).

More-detailed analyses of the freeway and arterial (street) networks in L.A. County reveal that congested travel conditions are ubiquitous on the freeway network, that freeway-travel times are extremely unreliable from one day to the next, that arterial congestion is especially intense on the Westside, and that truck traffic is most severe on the highways and around the ports and downtown Los Angeles.

Illustrating the first point, the map in Figure S.3 shows the average number of hours per day, for weekdays in 2006, during which the travel speed on different links in the L.A. County freeway network averaged less than 35 miles per hour (mph) (averaged across both directions of flow). Congestion appears to be especially severe on Interstate 5 near the Orange County border and on U.S. Route 101 (the 101

Figure S.3
Hours per Day During Which Freeway Speeds Average Less Than 35 mph in General-Purpose Lanes, 2006 Weekdays



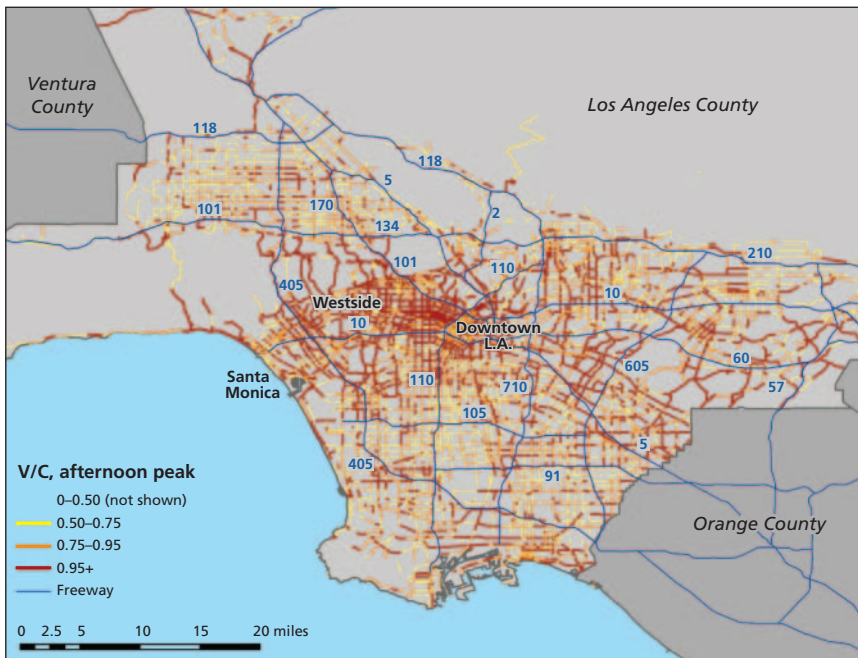
SOURCE: PeMS (undated).

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freeway) just northwest of downtown Los Angeles. Generally, though, congestion is prevalent throughout much of the freeway network, with many links experiencing four or more hours per day of travel speeds averaging less than 35 mph. And weekend travel conditions are not much better.

Figure S.4 captures the pattern of congestion on the arterial-street network in Los Angeles. Specifically, the map shows estimates of the volume-to-capacity (V/C) ratio for different arterial links in the afternoon peak travel hours as of 2004 (as the V/C ratio approaches 1.0, shown in darker lines on the map, congestion intensifies). Here we see that, while there are many congested arterials throughout the county,

Figure S.4
Modeled Arterial Volume-to-Capacity Estimates for the Afternoon Peak, 2004



SOURCE: 2004 regional transportation-model data provided by SCAG staff.

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the pattern is especially pronounced between downtown Los Angeles and the Westside.

What Makes Los Angeles Different?

To further inform the development of suitable congestion-reduction strategies for Los Angeles, we took a closer look at some of the underlying factors that contribute to the region's congestion. What is it about Los Angeles, specifically, that leads to the most severe congestion in the nation, and what implications does this have for the types of strategies that might offer the greatest prospects for reducing congestion?

Simple Explanations Fail to Explain the Severity of Congestion in Los Angeles

The results of our inquiry offered some surprises. Many of the assumptions that observers might make about the causes of congestion in Los Angeles turn out to be either incomplete or inaccurate.

L.A. residents do not drive more than other urban dwellers.

There is a common perception that Southern Californians have a long-standing love affair with their automobiles, and the severity of congestion in Los Angeles reinforces the assumption that residents of the region drive more than their counterparts elsewhere. In fact, this turns out not to be the case. Among the 14 largest metropolitan areas evaluated in TTI's annual mobility studies (Schrank and Lomax, 2007), the greater L.A. region ranks just

- fifth in daily per capita VMT, after Dallas, Houston, Atlanta, and Detroit
- fifth in average household automobile ownership, after Seattle, Atlanta, San Francisco, and Dallas
- ninth in the percentage of employees who drive to work alone, after Detroit, Dallas, Houston, Atlanta, Miami, Phoenix, Boston, and Philadelphia.

Los Angeles has a very extensive and well-managed road network. Another possible explanation might be that the region simply needs to add more road capacity. Yet among the 14 largest metropolitan areas considered by TTI, Los Angeles has by far the densest road network, providing more than 50 percent more lane-miles per square mile than Detroit, its nearest competitor. Even when framed in terms of lane-miles per capita, Los Angeles still ranks eighth among the 14 largest metropolitan areas. Moreover, state and local transportation agencies have implemented sophisticated programs, such as ramp metering and synchronized traffic signals, to use the road system as efficiently as possible.

Los Angeles provides a significant level of transit service. Proponents of alternative transportation might argue that the severity of congestion in Los Angeles stems not from a lack of sufficient road supply, but rather from inadequate provision of competitive transit services. Yet according to statistics from the American Public Transportation Association (APTA, 2007) and TTI (Schrank and Lomax, 2007), the transit system in Los Angeles appears robust in comparison to many other urban areas. Of the 14 largest metropolitan areas evaluated by TTI, Los Angeles ranks

- second in total bus-service miles, after New York
- first in bus-service miles per square mile
- third in bus-service miles per capita, after San Francisco and Washington, D.C.
- fifth in total rail-transit track-miles (including commuter rail, light rail, and subways), after New York, Chicago, Philadelphia, and Boston
- seventh in rail-transit track-miles per square mile, after New York, Chicago, Philadelphia, San Francisco, Boston, and Washington, D.C.
- seventh in rail-transit track-miles per capita, after Philadelphia, Boston, New York, Chicago, San Francisco, and Washington, D.C.

High Regional Population Density Is a Key Contributor to Congestion in Los Angeles

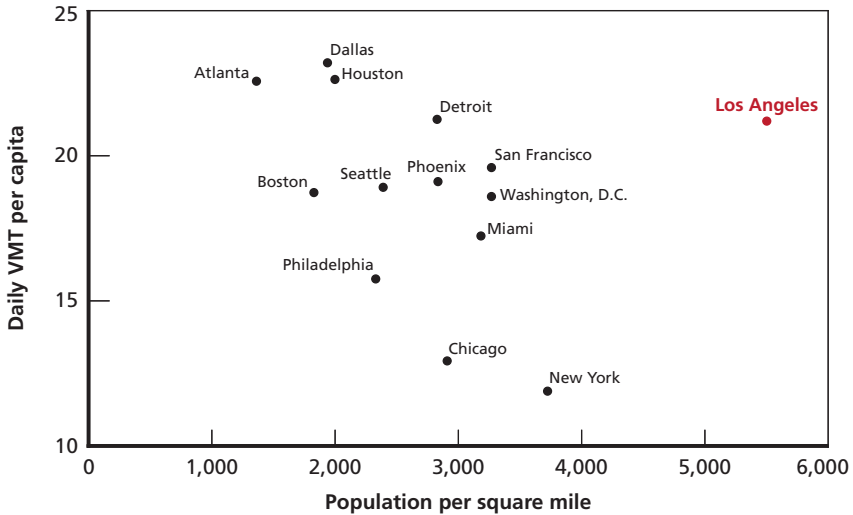
Despite its reputation for sprawling development, Los Angeles is quite densely populated at the regional scale. While downtown Los Angeles is not as dense as, say, Manhattan or downtown Chicago, the suburbs surrounding Los Angeles are much denser than the suburbs surrounding other major cities (Manville and Shoup, 2005). As a result, Los Angeles is by far the densest metropolitan area in the country.

As density increases, individuals tend to drive less on a per capita basis. This is because trip origins and destinations are often closer together, leading to shorter car trips, and people can rely on alternatives, such as walking, biking, or transit, for a larger share of trips. Yet this effect can be overwhelmed by the fact that there are also more drivers competing for the same road space, thus intensifying traffic congestion (Manville and Shoup, 2005). For instance, though Los Angeles has by far the densest road network among major metropolitan areas in the United States, as already noted, it still ranks second in terms of total VMT per total lane-miles, just behind San Francisco (based on data from Schrank and Lomax, 2007). In short, greater population density tends to exacerbate congestion, and Los Angeles is very dense.

High population density can also combine with other factors to make congestion worse. We mentioned earlier that L.A. residents do not drive more than residents of other large areas. It turns out, however, that they drive a lot on a per capita basis considering the region's density; in other words, Angelenos do not seem to curtail their driving as much as one might expect in response to higher density. Figure S.5 compares regional population density with daily per capita VMT for the country's largest 14 metropolitan areas.

For most of the cities shown in the figure, there is a fairly consistent relationship in which per capita VMT declines with regional density. Los Angeles stands as an exception. The only other large metropolitan areas in the country with higher per capita VMT (Atlanta, Dallas, Houston, and Detroit) are all much less dense than Los Angeles. For regions in which the level of density approaches that of Los Angeles, such as San Francisco, Washington, D.C., and New York, per capita VMT is much lower. We thus see a confluence of three density-

Figure S.5
Population Density and Daily Per Capita Vehicle-Miles Traveled in Major Metropolitan Areas



SOURCE: Schrank and Lomax (2007).

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related factors that, in combination, help to explain the severity of congestion in Los Angeles: (1) congestion is likely to rise with increased population density, (2) Los Angeles is much denser than its peers at the regional level, and (3) Los Angeles exhibits a surprisingly high level of per capita VMT relative to its density.

Land-Use Patterns in Los Angeles Make It Harder to Provide Effective Transit and Reinforce Reliance on the Automobile

One of the reasons that L.A. residents may drive more than one might expect given the region's density pertains to the prevailing land-use patterns. Rather than a single dominant downtown area such as one might find in New York or Chicago, Los Angeles has numerous high-density clusters scattered throughout the region—such as Santa Monica, Century City, Long Beach, Glendale, and Pasadena. This pattern, often described as *polycentricity* (multiple centers), can, in fact, ease traffic congestion by spreading car trips out over a greater percentage of the

road network's lane-miles. Within the context of Los Angeles, however, polycentricity may serve to exacerbate congestion in two ways.

First, polycentricity makes it more challenging to develop a well-connected, high-speed transit network with dedicated right-of-way to attract more riders and, in turn, reduce automotive travel. To begin with, the network will require more links to connect all of the dispersed population clusters and job centers with one another. Consider, for instance, that Los Angeles has constructed significant light-rail and subway track mileage in the past several decades, yet there are still obvious gaps in the network's coverage, such as between downtown Los Angeles and the Westside and between the San Fernando Valley and the Westside. In addition, the fact that population and jobs are spread out across more centers increases the difficulty of attracting sufficient ridership on any given link to justify the significant investment required for transit lines with dedicated right-of-way.

Second, polycentricity increases the likelihood that residents will need to visit multiple locations to accomplish multiple errands as opposed to taking care of multiple errands all at a single destination. The need to visit multiple locations makes transit—often slower and less convenient than driving—even less attractive by comparison. In short, the polycentricity of Los Angeles makes transit more difficult to provide and less attractive to use, despite the region's high population density, thereby reinforcing automobile dependency—and, in turn, exacerbating congestion.

Cheap and Abundant Parking in Los Angeles Encourages Additional Driving, Further Compounding Congestion

Compared to other large metropolitan areas, and especially in relation to the density of the region, Los Angeles offers abundant and inexpensive parking, and this encourages more people to drive (Manville and Shoup, 2005). In many areas, such as San Francisco, a deliberate effort by planners to reduce private vehicle use limits the number of parking spaces that may be included in a new development. In contrast, developers in most L.A. jurisdictions are required through zoning provisions to provide some minimum number of parking spaces (based on land-use type and project scale), thus ensuring that parking will remain

cheap and abundant and cars will remain the dominant mode of travel (Shoup, 2005).

Significant Freight Traffic Also Contributes to the Severity of Traffic Congestion in Los Angeles

Though this book does not consider traffic-reduction strategies directly related to goods movement, in diagnosing the sources of traffic congestion in Los Angeles, it is necessary to acknowledge the significant and growing role of freight traffic in the region. The twin Ports of Los Angeles and Long Beach collectively handle about 43 percent of the container shipments entering the United States, and the volume is expected to increase considerably in the coming decades (SCAG, 2005). Trucks transport many of the containers moving through these ports to inland freight hubs or other regional destinations. While truck traffic is not distributed uniformly throughout the region's road network, it does constitute a significant share of traffic in certain areas and along certain corridors.

What Short-Term Congestion-Reduction Strategies Are Available, and What Are Their Relative Strengths and Weaknesses?

To identify potential short-term measures for reducing congestion in L.A. County, RAND researchers reviewed the scholarly literature, examined prior studies and proposals for Los Angeles, and investigated current approaches being pursued in other large cities in the United States and abroad. This effort led us to consider 28 strategies that can be divided among three broad categories:

- *Transportation system management (TSM)*. Strategies in this category, such as traffic-signal timing and control and freeway-ramp metering, are intended to increase the efficiency of the existing road network.
- *Transportation demand management (TDM)*. Strategies in this category, such as ride-sharing, flexible work hours, and congestion

pricing, are intended to reduce or manage the demand for automotive travel, especially during peak hours. Subcategories include voluntary or incentive-based programs, regulatory approaches, and pricing strategies.

- *Alternative transportation options.* Strategies in this category, such as bus rapid transit (BRT) and bicycle-infrastructure improvements, are intended to increase the attractiveness or lower the price of alternatives to driving. Subcategories include transit strategies and nonmotorized strategies (bicycle and pedestrian improvements).

The full set of the 28 strategies is shown in Figure S.6. To gain insight into their relative advantages and limitations, we evaluated each option against a broad range of criteria:

- net cost/revenue implications for local government
- short-term effectiveness in reducing congestion
- longer-term effectiveness in reducing congestion
- accessibility, mobility, and traveler choice
- safety
- economic efficiency
- environment
- equity
- interest-group concerns
- general political obstacles
- institutional or jurisdictional challenges
- level of current implementation in Los Angeles.

We considered available options at the strategic level rather than looking at project-specific details, and the scope of the analysis did not allow for formal transportation-system modeling. We thus found it necessary to develop a qualitative system of ratings for characterizing each strategy with respect to these criteria (for example, a strategy might receive a rating of *negligible*, *low*, *medium*, or *high* to describe its longer-term effectiveness in reducing congestion). The strategy ratings were based on available evidence from the research literature (for

Figure S.6
Qualitative Ratings for the 28 Strategies Considered

Strategy	Public-Sector Cost/Revenue Implications	Short-Term Congestion Reduction	Long-Term Congestion Reduction
	High cost High revenue	Negligible High	Negligible High
TSM strategies			
Freeway ramp metering			
Signal timing and control			
HOV lane strategies			
Park-and-ride facilities			
Officers at intersections			
Left-turn signals			
Curb-parking restrictions			
One-way streets			
Rush-hour construction bans			
Incident management			
Voluntary TDM			
Ride-sharing			
Telecommuting			
Flexible work hours			
Car-sharing			
Traveler information systems			
Regulatory TDM			
Mandatory TDM programs			
Driving restrictions			
Pricing			
HOT lanes			
Cordon congestion tolls			
Variable curb-parking rates			
Parking cash-out			
Local fuel taxes			
Public transit			
Variable transit fares			
Deep-discount transit passes			
BRT			
Bus route reconfiguration			
Nonmotorized Travel			
Pedestrian strategies			
Bicycle strategies			

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performance-related criteria) as well as interviews with knowledgeable staff at state, regional, and local transportation agencies operating in L.A. County (for the current level of implementation in Los Angeles).

Figure S.6—Continued

Strategy	Other Transportation Goals	Other Social Goals	Implementation Obstacles	Current Implementation in Los Angeles
	Very bad Very good	Very bad Very good	High Low	None Advanced
TSM strategies				
Freeway ramp metering				
Signal timing and control				
HOV lane strategies				
Park-and-ride facilities				
Officers at intersections				
Left-turn signals				
Curb-parking restrictions				
One-way streets				
Rush-hour construction bans				
Incident management				
Voluntary TDM				
Ride-sharing				
Telecommuting				
Flexible work hours				
Car-sharing				
Traveler information systems				
Regulatory TDM				
Mandatory TDM programs				
Driving restrictions				
Pricing				
HOT lanes				
Cordon congestion tolls				
Variable curb-parking rates				
Parking cash-out				
Local fuel taxes				
Public Transit				
Variable transit fares				
Deep-discount transit passes				
BRT				
Bus route reconfiguration				
Nonmotorized Travel				
Pedestrian strategies				
Bicycle strategies				

NOTE: HOT = high-occupancy toll.

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In judging the potential effects of a strategy, we assumed that implementation efforts would be well planned and systematically applied throughout the county in sensible contexts.

Figure S.6 lists the 28 strategies evaluated and summarizes the qualitative ratings for all of the criteria considered. Note that the “Other Transportation Goals” column refers to accessibility, mobility, and traveler choice; that the “Other Social Goals” column represents a composite score based on safety, economic efficiency, environment, and equity; and that the “Implementation Obstacles” column represents a composite score based on interest-group concerns, general political obstacles, and institutional or jurisdictional challenges.

The Short List: 13 Strategies for Reducing Congestion and Improving Transportation Options in L.A. County Within Five Years

While the strategy assessments summarized in Figure S.6 provide helpful insights into the advantages and limitations of available options, the fact that they are qualitative—that is, that they are based to some degree on judgment and interpretation—suggests that it would be inappropriate to rely solely on the ratings in developing specific recommendations for Los Angeles. Instead, we first returned to the general insights about congestion and to the specific challenges faced in Los Angeles reviewed earlier in this summary. Based on this information, we constructed an integrated policy framework offering the greatest prospects for reducing congestion and improving transportation options within the L.A. context. With this framework in place, we then relied on individual strategy ratings (as well as the supporting research on which the ratings were based) for guidance in selecting options that would best support the broader aims embedded in the policy framework.

A Policy Framework for Reducing Congestion and Improving Transportation Alternatives in Los Angeles

In reviewing and integrating general insights about the phenomenon of congestion—its causes, its behavior, and its potential cures—as well as the specific contextual challenges faced in Los Angeles, several key themes emerged.

Absent significant policy intervention, congestion in Los Angeles will likely worsen in the coming years. Congestion results from an imbalance in the supply of and demand for road space. For several reasons—including diminished fiscal capacity and resistance among affected communities—significant expansion of the existing road network is unlikely. Notwithstanding the current economic downturn and run-up in fuel prices, meanwhile, forecasted growth in population, the economy, and goods movement suggest that automobile and truck travel will continue to expand in the longer term. Given the non-linear relationship between traffic volume and travel speed, even small increases in peak-hour driving could make congestion in Los Angeles much worse. The bottom line, then, is that we should be concerned about not just the short-term effectiveness of strategies but the longer-term effectiveness as well.

Managing the demand for peak-hour automotive travel offers the greatest prospects for reducing congestion in Los Angeles. Los Angeles already has a very dense road network that is operated at a high level of efficiency. Significant opportunities to expand or enhance the efficiency of the road network are therefore unlikely. On the other hand, residents of Los Angeles drive a lot relative to the regional population density of the region. Finding ways to manage the demand for driving during the peak hours thus appears to be the most promising—indeed, perhaps the only realistic—way to reduce congestion.

Only pricing strategies can effectively manage automotive demand in the longer term. While many strategies can help reduce congestion in the short term, only pricing strategies resist the effects of triple convergence. And provided that prices are allowed to rise as needed in response to general increases in the demand for automotive travel in future years, pricing strategies will continue to be effective in reducing congestion in the longer term as well. Pricing will also facilitate more-efficient use of existing capacity and raise needed revenue for transportation investments in the region. The latter is especially important given the decline in federal and state excise fuel-tax revenues.

Significant alternative transportation improvements will also be essential. Certain forms of pricing may introduce concerns regarding the ability of lower-income drivers to pay the resulting charges. To mit-

igate such concerns, it will be essential to offer significantly improved (faster, more reliable, and more convenient) transit options throughout the region. The density of population in Los Angeles is another argument for improving alternatives; with greater density, as argued, it becomes much more difficult to preserve unfettered automobility. Fortunately, it also becomes more realistic to accommodate a greater share of trips via transit, biking, or walking.

Taken collectively, these themes suggested an integrated policy framework offering the greatest prospects for reducing congestion and improving transportation options in Los Angeles. The framework incorporates the following three elements:

- Rely on pricing to manage peak-hour automotive demand, raise needed revenue, and promote more-efficient use of existing capacity.
- Significantly improve transit and other alternative modes.
- Continue to improve the efficiency of the road network but with a shift in emphasis from moving cars to moving people.

Selecting Strategies to Support the Integrated Policy Framework

The next step was to identify strategies that could support the aims of the integrated policy framework most effectively. Here, we relied on the individual strategy ratings for guidance, though we focused on different criteria depending on the role that a given strategy might play within the framework. For example, with pricing strategies, we were especially interested in longer-term performance in reducing congestion, as well as revenue implications, while for alternative transportation and TSM measures, we placed greater emphasis on such factors as cost implications, shorter-term effectiveness in reducing congestion (for TSM options in particular), and other transportation goals, such as mobility, accessibility, and traveler choice. For all strategies, we looked at the current degree of implementation in Los Angeles to understand whether there might be further benefits resulting from additional investment.

We also considered the level of implementation obstacles, such as political opposition, that each of the strategies might be expected to

face. Note, however, that a high rating for implementation obstacles would not necessarily rule out the inclusion of a particular strategy; as discussed earlier, most of the easy strategies have already been implemented, and it is expected that many of the more promising strategies are likely to raise at least some political challenges.

A final factor in the analysis was the manner in which different strategies interacted in either complementary or contradictory ways (note that the many possible interactions among 28 different strategies, discussed at length in the appendixes of this book, are difficult to summarize succinctly and thus are not included in Figure S.6). In short, our goal was to select a set of strategies that mutually complemented and reinforced one another.

Based on our analysis, we arrived at a total of 13 recommended strategies for Los Angeles (one of the recommendations spans three distinct strategies, so in total, we selected 15 of the 28 options considered). Of these, 10 appear unambiguously compelling—offering benefits that easily exceed costs—and can be pursued without delay. These are described as our *primary* recommendations. The remaining three also appear quite promising but are subject to some uncertainty: They either require additional study or depend on the outcomes of events currently unfolding in Los Angeles. We thus describe these as our *contingent* recommendations.

Table S.1 introduces, in summary form, the 13 recommendations. The table also indicates the principal goals from the integrated policy framework that each recommendation is intended to support. The table lists the primary recommendations first, followed by the contingent recommendations. Note that we have not attempted to prioritize further among the recommendations within each of the two broad categories; rather, the order of presentation simply follows the same sequence from Figure S.6: TSM measures followed by TDM measures (including pricing) followed by alternative transportation measures.

That a given strategy was not included as a recommendation does not indicate that it lacks merit. There were, in fact, four broad reasons that certain strategies were excluded from the final list:

**Table S.1
Strategy Recommendations and Policy Objectives**

Recommended Strategy	Manage Peak-Hour Automotive Travel	Raise Transportation Revenue	Improve Alternative Transportation Options	Use Existing Capacity More Efficiently
Primary recommendations				
1. Improve signal control and timing where deficient			○	●
2. Restrict curb parking on busy thoroughfares			○	●
3. Create a network of paired one-way streets			○	●
4. Promote ride-sharing, telecommuting, and flexible work schedules	○		●	
5. Develop a network of HOT lanes	●	○	●	●
6. Implement variable curb-parking rates in commercial centers	●	●		●
7. Enforce parking cash-out law at the municipal level	●			

Table S.1—Continued

Recommended Strategy	Manage Peak-Hour Automotive Travel	Raise Transportation Revenue	Improve Alternative Transportation Options	Use Existing Capacity More Efficiently
8. Promote deep-discount transit passes		◦	●	
9. Expand BRT with bus-only lanes			●	
10. Implement a regionally connected bicycle network			●	
Contingent recommendations				
11. Evaluate incident management for the arterial network				●
12. Evaluate potential applications of cordon congestion tolls	●	●		◦
13. Levy local fuel taxes to raise transportation revenue	◦	●		

NOTE: ◦ = an additional goal that a recommendation may help support. ● = a primary goal that a recommendation is intended to accomplish.

- Based on the evidence, the strategy did not appear to be effective in accomplishing its aims.
- The strategy appeared to be effective, but other options for achieving the same goals offered even greater promise.
- The strategy appeared to be effective, but the current level of implementation in Los Angeles is sufficiently advanced that further investment would likely yield diminishing returns.
- The strategy would work at cross-purposes with other options included in the final set of recommendations.

We now summarize the 10 primary and three contingent recommendations developed in this book. For each, we review the key motivating factors for including the strategy, outline likely obstacles that may arise, and discuss possible implementation steps.

Primary Strategy Recommendations

Recommendation 1: *Prioritize and fund investments in upgraded signal timing and control in cities where the current technology is deficient, coordinate signal timing between jurisdictions, and ensure that newly installed technology enables signal prioritization for BRT.*

- **Motivation:** Improving the timing and control of traffic signals can lead to significant reductions in delays at arterial intersections, and many cities in the region—most notably the City of Los Angeles— have already invested heavily in this approach. Yet cities with fewer resources often rely on outdated and much less effective timing and control mechanisms, contributing to congestion on the arterial network. Additionally, signal timing and control are often uncoordinated between different cities, leading to bottlenecks at city boundaries. Upgrading signal timing and control technology and improving interjurisdictional coordination will help to reduce delays and will also create the opportunity to implement signal prioritization for faster bus service.
- **Implementation obstacles:** The primary obstacle is funding, as the acquisition and installation of signal timing and control technology is very expensive. To illustrate, the City of Los Angeles

recently received \$150 million for traffic-signal synchronization improvements from state bond revenues. This will enable the City of Los Angeles Department of Transportation (LADOT) to add 1,117 signals to its current signal-control system, upgrade an additional 1,256 signals to the most recent technology, and add 340 traffic-tracking cameras to help monitor intersections.

- **Implementation steps:** Signal timing and control is most deficient in cities that lack sufficient resources to invest in the most up-to-date technology. We therefore recommend that this effort be funded and coordinated at the county level, likely by the L.A. County Metropolitan Transportation Authority (Metro). The initial implementation steps will include (1) conducting a countywide survey of existing signal technology and current traffic conditions on the arterial network so as to prioritize investments and (2) identifying or developing a revenue stream to fund these investments. Follow-on steps will include the provision of priority-based funding and technical assistance to cities for the installation and integration of signal timing and control technology. As a condition for receiving this assistance, we also recommend that cities be required to support efforts to coordinate signals at municipal boundaries and allow for signal prioritization to support more-effective BRT service.

Recommendation 2: *Restrict peak-hour curb parking on all congested thoroughfares and dedicate the additional capacity to bus-only lanes where merited.*

- **Motivation:** Prohibiting curb parking on congested thoroughfares during the peak hours can reduce delays by increasing available lane capacity at little cost. We recommend restricting curb parking on all major arterial corridors throughout the region subject to recurring congestion and actively enforcing the restrictions (through prompt ticketing and towing) to ensure their effectiveness. In corridors where the curb lane could carry more total passengers in bus-only mode, we further recommend restricting the lane to bus-only travel during peak hours.

- **Implementation obstacles:** Businesses may object that curb-parking restrictions will reduce parking capacity for their patrons, while neighboring communities may be concerned that more vehicles will need to park on the surrounding residential streets. Applying this strategy systematically on all large boulevards throughout the region will reduce perceptions that certain businesses or neighborhoods are being treated unfairly. Another option for overcoming opposition may be to install parking meters in surrounding residential neighborhoods for the use of visitors under the condition that resulting revenues would be allocated to public improvements that would benefit local residents (e.g., repairing sidewalks, burying utility lines, or creating pocket parks). This could create enthusiasm among surrounding neighborhoods for the idea of allowing visitors to pay for the privilege of parking on their streets, yielding a win-win result.
- **Implementation steps:** The first step will be to identify congested major arterial thoroughfares that allow curb parking during peak hours. At the same time, corridors with significant bus service should be evaluated for the potential to create bus-only lanes. The next step will be to implement curb-parking restrictions systematically, creating bus-only lanes where merited.

Recommendation 3: *Develop a network of paired one-way streets in high-volume travel corridors throughout the region.*

- **Motivation:** Converting streets from two-way to one-way operation will increase road capacity, as the median strip will no longer be required (i.e., it can be converted to a travel lane). It will also reduce delays by enabling progressive signal timing in the direction of travel and making it easier and faster to make left turns. We also recommend the development of bus-only lanes and bicycle lanes on the system of one-way streets.
- **Implementation obstacles:** Local businesses may prefer two-way streets with slower-moving traffic so that potential customers will not speed past a store without seeing it. One-way-street proposals are often combined with curb-parking restrictions, and

local businesses may oppose this as well. Owners of surrounding homes may fear more cut-through traffic when vehicles need to backtrack, and they may also be concerned that higher travel speeds will diminish the pedestrian environment and introduce safety risks. While our review of the evidence suggests that one-way streets tend to be safer than two-way streets, evidence on increased neighborhood cut-through traffic is less definitive.

- **Implementation steps:** The first recommended step is to implement paired one-way streets on Pico Boulevard and Olympic Boulevard, a proposal that has already received considerable attention, with the provision that a lane be dedicated to bus-only service in the peak hours (see the plan by Rifkin, 2007). While implementing one-way streets with bus-only lanes on Pico and Olympic, city planners can examine other corridors where paired one-way streets might offer similar opportunities. Given the density of arterial traffic on the Westside (see Figure S.4), this should be an area of initial focus. Assuming that the Pico/Olympic project proves successful, the implementation of other paired one-way streets would then proceed.

Recommendation 4: *Bolster outreach efforts to promote voluntary TDM—including ride-sharing, telecommuting, and flexible work schedules—at businesses and other large organizations throughout the county.*

- **Motivation:** Within the context of our integrated policy framework for Los Angeles, the implementation of pricing strategies will require improved alternatives to driving alone during peak hours. The three strategies encompassed by this recommendation—ride-sharing, telecommuting, and flexible work schedules (e.g., four 10-hour days per week)—all present viable options for either avoiding peak-hour driving or not driving at all. Current media reports suggest that with the recent run-up in fuel prices—which should have an effect on driving behavior similar to that of pricing strategies—many auto commuters are already seeking other options to save on their gasoline bills. Our recommendation is

that a regional agency, such as Metro, devote greater funding to assist employers in developing voluntary TDM programs to create additional commuting options for their employees. We also recommend expanded support for related programs, such as dynamic ride-matching.

- **Implementation obstacles:** Our purpose in recommending enhanced promotion of ride-sharing, telecommuting, and flexible work schedules is not to manage the demand for peak-hour automotive travel (though it may help support that aim); that role is filled instead by our pricing recommendations. Rather, within the context of our integrated policy framework, these traditional TDM measures are intended to provide travel options that would enable commuters to avoid paying higher fuel prices as well as the tolls that would be applied with some of the pricing strategies. Accordingly, our recommendation calls for voluntary rather than mandatory measures. Political obstacles are thus not likely; rather, the primary obstacle will be related to securing the necessary funding for the effort.
- **Implementation steps:** One of the first steps will be for Metro (or any other agency that chooses to take the lead on this) to review available research and best practices to develop a toolbox of approaches that employers can implement to increase ride-sharing, telecommuting, and flexible work schedules for their employees. The potential to enhance dynamic (ad hoc) ride-sharing options—among commuters as well as other travelers—also merits further attention. A second initial step will be to secure additional funding to support outreach efforts to employers as well as to further subsidize specific TDM programs already under way (such as the CommuteSmart regional ride-matching program and Metro’s existing vanpool program). Follow-on activities will then consist of direct outreach and interaction with employers to provide assistance for ride-sharing, telecommuting, and flexible-schedule options for their employees.

Recommendation 5: *Develop a network of HOT lanes on freeways throughout the county and apply any net revenue to the subsidization of express bus service in the HOT lanes.*

- **Motivation:** HOT lanes carry both carpools and single-occupant vehicles (SOVs). Solo drivers pay a toll that varies with demand to ensure that the lanes always remain free-flowing, while carpools, depending on the policies adopted, may travel for free, pay a reduced toll, or pay the full toll (even in the latter case, however, carpoolers still save on tolls on a per-person basis). HOT lanes offer several key benefits. They provide a valuable opportunity to pay for faster and more reliable travel time for trips (such as to the airport, to a doctor's appointment, or to day care) when there is a high value for arriving on time. Evidence from existing HOT lanes shows that drivers from all income groups value and make use of this option. By maintaining free-flowing travel speeds, HOT lanes also carry far more vehicles per hour than congested free lanes do, thus enhancing the capacity of the freeway without adding more lanes. As an additional benefit, buses can use HOT lanes, thus improving transit services in the region. The fact that congestion is severe on most highways in the county (see Figure S.3) serves as motivation for developing a network of HOT lanes rather than one or two stand-alone applications.
- **Implementation obstacles:** Because HOT lanes offer many benefits, and because use of the HOT lanes is optional rather than mandatory, this strategy enjoys a high degree of public support in places where it has been implemented (Sullivan, 2000; Supernak et al., 2002). Within Los Angeles, however, two implementation obstacles will need to be overcome. First, some freeways do not have high-occupancy-vehicle (HOV) lanes that could be converted to HOT lanes. Second, many of the existing HOV lanes are already operating at or near full capacity during the peak hours such that there would be little space to sell to SOVs. To develop a full network of HOT lanes, it will therefore be necessary to consider such options as (1) converting current general-purpose lanes to HOT lanes, (2) increasing the number of passengers required

(e.g., from two or more to three or more) to qualify as an HOV in order to free up additional space in the lane, or (3) requiring that both SOVs and carpools pay the toll (note that the desire to split a toll among multiple vehicle occupants may continue to encourage the formation of carpools). Each of these actions is likely to face opposition. Enabling state legislation will also be required.

- **Implementation steps:** We recommend beginning with a HOT-lane demonstration project on the Interstate 110 (I-110) Harbor Transitway facility to familiarize L.A. residents with the benefits of this strategy. The Harbor Transitway, an 11-mile HOV and bus facility opened in 1996, is an ideal initial candidate, as it already includes two lanes flowing in each direction, which allows for smoother operation. The next step will be to develop a plan to provide HOT lanes on all congested freeways in the county. This may require, as noted, the conversion of existing general-purpose lanes in some cases and the modification of HOV passenger limits in others.

Recommendation 6: *Implement variable curb-parking charges in all busy commercial and retail districts, returning a share of the revenue to local merchants to invest in public amenities and using the remainder to fund municipal transportation investments.*

- **Motivation:** Varying parking charges by location and time of day to ensure that there will usually be one or two free spaces available on any block will lead to significant reductions in congestion in busy commercial and retail areas by eliminating the need for visitors to drive around searching for an available space. If implemented broadly throughout the region, net revenues will likely fall in the range of tens to hundreds of millions of dollars annually.
- **Implementation obstacles:** Implementing variable curb-parking rates may require investment in new meter technology, but increased parking revenues should easily offset the initial capital cost. Retailers may also fear that higher parking charges will drive customers away; though this proves not to be the case (Shoup, 2005), returning a share of the increased parking revenue to local

merchants for investments in public amenities can still be useful in overcoming this potential opposition.

- **Implementation steps:** Cities can pursue this action immediately. Key steps include installing the necessary metering technology and developing a city ordinance specifying that prices will be allowed to vary such that a few spaces remain vacant on each block. The legislation should also establish that local districts will receive a portion of the resulting revenue for investing in public improvements.

Recommendation 7: *Enforce the existing California parking cash-out law at the municipal level in cities where a significant share of employers lease parking.*

- **Motivation:** With parking cash-out, workers whose employers lease parking on their behalf are given the option of receiving cash in lieu of free parking. This creates a strong financial incentive to carpool, walk, bike, or take transit instead of driving alone to work, thereby reducing the number of commuters on the road.
- **Implementation obstacles:** California requires that firms with more than 50 employees who lease parking for their employees offer the cash-out option, but the law is not enforced. We are recommending that cities take the necessary steps to enforce the law in place of the state. The primary challenges are likely to fall in the legal and administrative categories, but it is not anticipated that they will be difficult to overcome. Importantly, businesses are unlikely to oppose this strategy because (1) the parking cash-out option is viewed as a valuable employee benefit and (2) it costs little to implement, since the law applies only to firms that lease parking and can choose to offer the cash instead of paying the lease (Shoup, 1997).
- **Implementation steps:** Cities can pursue this strategy immediately. The City of Santa Monica already requires parking cash-out for qualifying employers, and the City of Los Angeles is exploring a promising approach under which employers that lease parking would be required to offer parking cash-out as part of

the business-permitting process. Parking cash-out should lead to significant reductions in the number of employees who drive alone to work, and we further recommend that parking cash-out programs be carefully monitored to quantify these effects. The resulting information can then serve as a basis for reducing off-street parking requirements for real-estate developments in which parking will be leased. Over time, as more office buildings with leased parking are developed, the number of employers able to offer parking cash-out will increase, thus expanding the benefits of the program.

Recommendation 8: *Develop and aggressively market deep-discount transit fares to employers in areas that transit serves well.*

- **Motivation:** Deep-discount-fare programs enable large organizations (such as universities or firms) to purchase transit passes for all members or employees at significant discounts. When structured properly, they lead to increased transit ridership, increased transit-operator revenues, and reduced transit operating deficits. And from the purchasing organization's perspective, they are often cheaper than providing additional parking or other transportation benefits. Whereas pricing strategies recommended in this book make driving more expensive, deep-discount passes reduce the cost of transit, thereby making it even more attractive by comparison. Successful deep-discount programs already exist in the L.A. region but have been applied only to a limited extent.
- **Implementation obstacles:** The principal obstacles are administrative and should not be difficult to overcome.
- **Initial implementation steps:** Metro and other transit providers in the county can begin efforts to develop and more aggressively market deep-discount-fare programs immediately.

Recommendation 9: *Expand BRT in urban areas with dedicated bus-only lanes on the arterial network and express freeway service in HOT lanes.*

- **Motivation:** This recommendation will significantly improve the speed, convenience, and reliability of public transit in Los Angeles at relatively low cost (in comparison with current estimates of \$400 million or more per mile to construct subways). The improved transit options will provide viable alternatives for those wishing to avoid the higher price of automotive travel that would result from pricing strategies and will benefit the many L.A. residents who already rely on the bus system for their daily travel needs. Thus, current transit users, new transit users, and those driving on less congested roads will all be better off. While the Metro Orange Line busway in the San Fernando Valley includes 14 miles of exclusive right-of-way, Metro Rapid bus lines share the streets with general traffic and must therefore suffer the same congested travel conditions. Metro Rapid lines include many features of the BRT concept that has taken the transit world by storm in recent years, including signal prioritization, more-frequent service, limited stops, real-time next-bus information at stops, and so on. These features have improved BRT travel speeds by about 20 to 30 percent over conventional local bus service (Metro, 2000). Yet absent partially or fully reserved rights-of-way, service is still slow in many places; the average daytime travel speed for Rapid buses along the Wilshire corridor, for example, is just 11 mph (Jeff, 2007a).
- **Implementation obstacles:** Allowing buses to travel in HOT lanes on the freeway network is a promising opportunity. On the arterial system, however, the primary obstacle to providing bus-only lanes is that many drivers are likely to argue that *all* vehicles should be allowed to use the lanes. Provided that a bus-only lane will facilitate greater total passenger (as opposed to vehicle) throughput in a corridor, however, reserving a lane for the exclusive use of bus transit represents the most efficient use of the capacity.
- **Implementation steps:** We recommend implementing bus-only lanes on Wilshire Boulevard in the curbside lane during peak travel hours—an idea already being evaluated by the City of Los Angeles and Metro—as a first step in developing a regional network of dedicated bus-only lanes on the arterial system. Bus service

along the Wilshire corridor already accommodates about 100,000 boardings each weekday; with faster travel speeds in a bus-only lane, ridership in the corridor should expand even further. The next steps will be to plan and implement a network of bus-only lanes on the arterial system and add express freeway bus service as HOT lanes are implemented. A key element of the planning effort will be to monitor the effects of the initial bus-only lanes on Wilshire, examining the outcomes with respect to bus travel speed and ridership. Based on this information, it should then be possible to examine ridership on other major arterial corridors and project how it might increase with the introduction of bus-only lanes during peak hours. In cases in which current ridership plus anticipated gains suggest that bus-only lanes will support greater total passenger throughput, the curb lane should be restricted to bus service during peak hours. Additional opportunities to create bus-only lanes may arise with the conversion of two-way streets to one-way operation and the restriction of curb parking on busy thoroughfares during peak hours.

Recommendation 10: *Develop an integrated, regionwide bicycle network, with a specific focus on dense urban areas where bicycles can serve a large share of trips.*

- **Motivation:** This recommendation falls under the category of improving alternatives to driving in Los Angeles. While cycling may not serve as a potential replacement for a long commute, it can certainly facilitate shorter trips (and cycling in combination with transit can serve longer trips). Los Angeles offers an ideal climate for cycling throughout much of the year, and many excellent bicycle facilities already exist. Yet the system is not clearly legible (i.e., easy to understand) to existing or potential riders, bicycle routes are not well connected at the regional level, and existing lanes often end abruptly at municipal boundaries. To make cycling a more viable mode of transportation in the region, especially in urban areas, we recommend the development of an integrated and legible regional bicycle network, including additional,

clearly identifiable bike lanes and bike paths along with improved bicycling amenities—such as bicycle-storage lockers—at transit hubs. Because bicycling can be more dangerous than driving per mile of travel (Pucher and Dijkstra, 2000), we also recommend additional expenditures on bicycle-safety training programs.

- **Implementation obstacles:** The principal obstacle to expanding the bicycle network in Los Angeles is insufficient funding combined with the relatively low prioritization given to bicycling facilities. There may be some institutional obstacles as well; bicycling improvements are typically implemented by individual cities, and not all cities in the county have been willing to devote road space to biking. To overcome concerns that bike lanes would reduce available space for automobiles on busy thoroughfares, it may be useful to consider opportunities for creating bike lanes on less heavily traveled routes.
- **Initial implementation steps:** We recommend allocating additional revenue to bicycling facilities and completing Metro’s existing Bicycle Transportation Strategic Plan (Metro, 2006) as a starting point. Further opportunities to expand the bicycle network may arise with the conversion of two-way streets to one-way operation.

Contingent Strategy Recommendations

Recommendation 11: *Evaluate the costs and benefits of implementing a regional incident-management system on the arterial network.*

- **Motivation:** Traffic incidents—including crashes and vehicle breakdowns—are responsible for a very large share of urban congestion. By facilitating faster detection of, response to, and clearing of such occurrences, incident-management systems can have a dramatic effect on reducing the resulting delays. Metro and the California Department of Transportation (Caltrans) already fund and manage an extensive Freeway Service Patrol (FSP) system that helps to accomplish these goals. We recommend testing a similar program on the arterial network and, should it prove successful, expanding it regionally. *Note that most incident-management*

systems implemented to date have focused on freeway operations, and thus there are few data to indicate how effective such a program would be on the arterial system; for this reason, we treat it as a contingent recommendation, one requiring further evaluation. (LADOT has reportedly experimented with an arterial-based incident-management program, but, as of this writing, the results of the evaluation were not available.)

- **Implementation obstacles:** Should arterial incident management prove to be a cost-effective strategy, the primary obstacle will be to secure funding for the program.
- **Initial implementation steps:** The first step, as noted, will be to evaluate the costs and benefits of an arterial incident-management system through some type of trial or demonstration project. If, based on the preliminary evaluation, arterial incident management proves to be cost-effective, the next step will be to implement an ongoing program. While individual cities could pursue this, there may be economies of scale to be achieved through regional implementation. In this case, Metro would likely be the lead agency, as it already manages the county's FSP program.

Recommendation 12: *Evaluate the potential for implementing cordon congestion tolls around major activity centers in the region.*

- **Motivation:** Cordon congestion tolls apply a charge for any vehicle that enters or travels within a designated cordon area (for example, a central business district) during peak hours. This leads to significant congestion reductions within the charging zone and confers additional benefits, such as fewer traffic accidents and reduced vehicle emissions. Cordon tolls can also raise hundreds of millions of dollars per year. *To date, however, cordon tolls have been implemented only in relatively large, centralized cities with extremely well-developed transit systems. It remains unclear whether cordon tolls could be equally effective in the L.A. context without creating legitimate equity concerns. We thus categorize cordon tolls as a contingent recommendation and suggest that further research be conducted prior to pursuing implementation.*

- **Implementation obstacles:** To implement cordon tolls in Los Angeles, three obstacles will need to be overcome. First, Los Angeles is much more polycentric than other cities where this approach has been employed; as a result, it may be appropriate to consider multiple cordon-toll areas. Second, because cordon tolls (unlike HOT lanes) are required of most drivers who enter the zone, they raise concerns that lower-income drivers might be disproportionately burdened by the cordon charges (Santos and Shaffer, 2004). Such concerns make it necessary to provide high-quality transit service to any area subject to a cordon toll to ensure that there are viable alternatives to driving. While revenues raised by a cordon toll can help fund improved transit services in the longer term, many of the investments will need to occur before the cordon toll is implemented in order to effectively mitigate concerns. Third, the concept of cordon tolls does not enjoy a high degree of public support in Los Angeles, both because it is an unfamiliar idea and because most drivers expect that they would incur significant costs without appreciable travel-time savings. Educational outreach about the effectiveness of this approach along with efforts to build popular and political support would thus be necessary before such a program could be pursued. Choices about how to allocate the resulting revenue will be instrumental in helping to build support.
- **Implementation steps:** Cordon congestion tolls are complex, and the first required step will be to study the potential for their application in Los Angeles (note that Metro is currently funding such a study). Interrelated issues to address in the study include where to locate the cordon boundaries, what electronic tolling technology to employ, how to structure the tolls (e.g., flat rate versus varying by time of day), how to allocate the revenues, and how the cordon toll will affect different spatial and demographic segments of society. Given the high levels of congestion on both the freeways and the arterial network between the Westside and downtown Los Angeles, we suspect that such areas as downtown Los Angeles, Century City, Santa Monica, and Los Angeles International Airport (LAX) might emerge as promising candidates for cordon

tolls. Should the study find that cordon tolls would be feasible and beneficial, the next steps will be to conduct outreach, develop the necessary political consensus, and implement the recommended tolling zones. To mitigate equity concerns, fast and efficient transit options serving the charging zones will have to be established *before* the cordon-toll operations commence.

Recommendation 13: *Implement local fuel-tax levies at the county level to raise transportation revenues and (to a lesser extent) reduce the demand for driving.*

- **Motivation:** Failure to raise federal and state fuel taxes in recent years to keep pace with inflation and improved fuel economy has resulted in worsening transportation-funding shortfalls in Los Angeles and elsewhere. Los Angeles has, in the past, relied on sales-tax ballot measures to raise local transportation funds, but fuel taxes offer more compelling benefits. With fuel taxes, the amount one pays is based (roughly) on the amount one drives, and aligning costs and benefits can be viewed as more equitable (Wachs, 2003b). Fuel taxes also act as incentive to drive less, and this can help to reduce congestion. Further, fuel taxes encourage the purchase of more fuel-efficient vehicles, thus leading to important environmental benefits. Neither sales taxes nor other general-revenue sources offer these same advantages. To promote a more stable revenue stream and prevent the erosion of revenues against future inflation, we would recommend that local fuel taxes be structured on a cents-per-gallon basis and indexed to increase with either the consumer price index or the construction cost index. *Note that Metro is already taking steps to place an additional 0.5-percent sales tax to fund transportation improvements on the ballot in the fall of 2008, and it is unlikely that the county would simultaneously pursue a sales-tax measure as well as a local fuel-tax levy. Should the sales-tax effort stall, we would then recommend the development of a local fuel-tax measure in its stead. This leads us to categorize this as a contingent recommendation.*

- **Implementation obstacles:** Enabling state legislation would be required before local fuel taxes could be levied in Los Angeles. Assembly Bill (AB) 2558, recently introduced by Assemblymember Mike Feuer, could serve this purpose. AB 2558 would allow L.A. County to levy a carbon tax of up to 3 percent of the fuel purchase price (or roughly \$0.12 to \$0.15 per gallon at current fuel prices); though this represents a slight departure from our recommendation of structuring the tax on a cents-per-gallon basis indexed to rise with inflation, the broad intent of the measure is otherwise similar. Voters would then be required to approve the tax. Note, however, that we are using the term *tax* in the generic sense. From a technical perspective, Assemblymember Feuer has, in fact, attempted to structure AB 2558 as a user fee rather than as a tax (Newton, 2008). A key difference is that, under California law, user fees require only 50-percent voter approval (although there are more restrictions on the allocation of the revenue), whereas taxes require a two-thirds vote. Yet despite recent evidence that voters express growing support for efforts to link transportation funding with environmental goals (Dill and Weinstein, 2007), gaining even 50-percent voter approval may prove to be politically challenging given that (1) the economy appears to be weakening, (2) the cost of gasoline has been rising dramatically, (3) additional taxes will be viewed as burdensome for lower-income drivers, and (4) Metro is already pursuing a sales-tax measure for the current ballot cycle.
- **Initial implementation steps:** The first step, as noted, will be to pass enabling state legislation. The second step will be to gain voter approval, and this will require concerted efforts to build political support.

The 13 Recommendations, Collectively, Should Produce Substantial Benefits for Los Angeles

As discussed earlier, we did not examine available strategies in terms of project-specific details, nor did we rely on modeling for the analysis.

This precluded the ability to make specific predictions on the degree to which travel speeds might be improved and congestion reduced through the implementation of the 13 recommendations. Even so, there is ample evidence on how the strategies perform in cities where they have already been applied. If we assume that the strategies will work as well in Los Angeles as they have elsewhere (and we have no reason to suspect otherwise), then the benefits afforded by the recommendations should be considerable indeed. Here, we summarize evidence on the likely effectiveness of the recommendations in terms of reducing congestion, improving transportation alternatives, and raising needed revenue.

Increasing Travel Speed and Reducing Delays on the Road Network

- Signal timing and control investments in areas where the current technology is lacking or deficient can increase travel speeds by 10 to 22 percent and reduce travel times by 8 to 17 percent on the arterial network (LADOT, undated[b]; MITRE Corporation, FHWA, and USDOT, 1996).
- Peak-hour curb-parking restrictions with active enforcement can improve arterial travel speed by around 10 percent (Kumar, 2007).
- Paired one-way street conversions can increase travel speed by about 20 percent and reduce travel time by 20 to 30 percent (Cunneen and O'Toole, 2005; Rifkin, 2007; Stemley, 1998; TTI, 2001).
- HOT lanes can maintain free-flowing travel speeds (60 to 65 mph) during peak travel hours while carrying up to twice the volume that congested general-purpose lanes do (Obenberger, 2004).
- Cordon tolls can reduce traffic volume within the charging zone by about 15 percent, increasing average travel speeds by up to 100 percent (Fabian, 2003; Goh, 2002; Santos and Shaffer, 2004).
- Variable curb-parking rates can reduce traffic volumes in busy commercial and retail districts by about 30 percent on average and by up to 90 percent in at least one example (Shoup, 1997).

Making Alternative Transportation More Attractive and Convenient

- Parking cash-out can provide sufficient financial incentive for about 15 percent of employees to shift from driving to alternative modes (Shoup, 1997).
- Deep-discount transit fares can lead to transit ridership gains of up to 200 percent among members of participating organizations (Brown, Hess, and Shoup, 2001).
- BRT featuring bus-only lanes can result in much faster transit service at relatively low cost (Levinson, Zimmerman, Clinger, Rutherford, Smith, et al., 2003); evidence from the Metro Rapid system demonstrates that reductions in travel time stimulate proportional gains in ridership (Metro, 2000).

Raising Needed Transportation Revenue

- HOT lanes can raise sufficient revenue to subsidize express bus operations within the corridor (Obenberger, 2004; Poole and Orski, 2000; SANDAG, 2007).
- Cordon tolls can generate tens to hundreds of millions of dollars in annual net revenue (ECMT, 2006).
- Variable curb-parking rates can raise well over \$1 million in annual net revenue within a single urban retail district (Shoup, 2005). Implemented throughout the region, the strategy would likely raise tens or even hundreds of millions of dollars for municipalities in the region.
- A local fuel tax on the order of \$0.12 to \$0.15 per gallon in L.A. County would generate around \$500 million in annual revenue (“Feuer Introduces Package of Transportation Bills,” 2008).

These benefits are likely to accrue throughout many areas of L.A. County. While some of the strategy recommendations are tailored especially to dense urban areas, others promise to be equally effective in urban or suburban settings. Table S.2 provides a summary of the types of facilities (arterials versus freeways) and areas (suburban, urban,

Table S.2
Scope of Effects

Recommended Strategies	Facility		Area		
	Arterial	Freeway	Suburban	Urban	Commercial Center
Primary recommendations					
Signal timing and control	•		•	•	•
Curb-parking restrictions	•			•	•
One-way streets	•		•	•	•
Voluntary TDM	•	•	•	•	•
HOT lanes		•	•	•	•
Variable curb-parking rates	•				•
Parking cash-out	•	•		•	•
Deep-discount transit passes	•	•		•	•
BRT with bus-only lanes	•	•		•	•
Regional bicycle network	•			•	
Contingent recommendations					
Arterial incident management	•		•	•	•
Cordon congestion tolls	•	•			•
Local fuel taxes	•	•	•	•	•

or commercial center) in which we would expect the effects of each of the strategy recommendations to be most pronounced.

Key Dependencies and Interactions

We recognize that, as leaders consider the recommendations in this book, there may be a desire to focus only on those that seem to offer significant benefits without stirring political controversy. Against this possibility, we would like to reiterate two crucial observations to bear in mind. First, as indicated in the summary of benefits, both TSM and pricing strategies will help to reduce delays and improve travel speeds. Given the shorter-term effects of triple convergence, however, as well as the longer-term effects of general increases in the demand for automotive travel, the congestion-reduction benefits of TSM strategies are, in the end, likely to be short-lived. If Los Angeles hopes to achieve traffic-congestion reductions that are sustainable for the longer term, it is essential that the set of adopted policies include pricing strategies.

Second, though many of the strategies we have recommended would be highly effective if implemented on their own, there are many ways in which the recommendations, taken together, either complement or depend on one another. Stated another way, the whole of the recommendations can be considered as greater than the sum of its parts. While it may not prove possible to implement all of the strategies recommended here, Los Angeles would benefit greatly by implementing as many as possible as part of a coordinated and comprehensive effort. In the following paragraphs, we highlight three issues in which the complementarities and interdependencies among the 13 primary and secondary recommendations appear to be especially critical.

Funding: Many of the recommended strategies, but especially signal timing and control, extensive one-way-street conversions, arterial incident management, and BRT expansion, will require significant additional revenue. Cordon congestion tolls, variable curb-parking rates, and local fuel taxes all offer the potential to raise significant county or municipal transportation revenues to help in this regard. HOT lanes and deep-discount transit-fare programs can also provide modest net revenue.

Ability to pay: Cordon tolls—and, to a lesser extent, HOT lanes, variable curb-parking rates, and local fuel taxes—are likely to raise fairness concerns about the ability of lower-income drivers to afford the resulting charges. To mitigate these concerns, it will be essential to improve nonautomotive travel alternatives in the region through such strategies as voluntary employer trip-reduction programs, deep-discount transit fares, and enhanced BRT service featuring bus-only lanes on the arterial network and express bus service in HOT lanes on the freeways.

Competition for road space: One of the most promising short-term strategies for improving the speed and convenience of transit in Los Angeles is the creation of bus-only lanes in transit-rich arterial corridors, such as Wilshire Boulevard. Yet if these corridors are already congested, drivers are likely to object strenuously to the allocation of an existing lane to bus-only service, even if such treatment would facilitate greater overall passenger (as opposed to vehicle) throughput. Peak-hour curbside-parking restrictions and one-way-street conversions are both valuable in this context because they create *additional* lane capacity—that is, capacity not already claimed for general-purpose traffic. As a result, it may be easier, politically, to create bus-only lanes in tandem with curbside-parking restrictions or one-way street alignments than it would be to create bus-only lanes without these other changes.

Next Steps for L.A. County

While individually and collectively promising, each of the strategy recommendations involves change from the status quo and thus is likely to engender resistance from some group of stakeholders. So how to begin? What must Los Angeles do to implement these recommendations and get on with relieving the region's congestion problems?

Table S.3 examines this question from a jurisdictional perspective, summarizing the roles that various governmental entities would likely need to fulfill in implementing the recommendations. Note that many of the strategies could involve multiple actors. *Lead* indicates that a particular governmental entity would likely assume leadership for

**Table S.3
Public-Sector Implementation Roles**

Recommended Strategies	State Legislature	Caltrans	Metro as RTPA	LACDPW	Cities (DOTs)	Transit Operators
Primary recommendations						
Signal timing and control			Lead	Required	Required	
Curb-parking restrictions					Lead	
One-way streets			Optional		Lead	
Voluntary TDM			Lead		Optional	
HOT lanes	Required	Required	Lead		Optional	
Variable curb-parking rates					Lead	
Parking cash-out					Lead	
Deep-discount transit passes						Lead
BRT with bus-only lanes					Required	Lead
Regional bicycle network			Lead		Required	
Secondary recommendations						
Arterial incident management			Lead		Optional	
Cordon congestion tolls	Required	Required	Required		Lead	Required
Local fuel taxes	Required		Lead			

NOTE: RTPA = regional transportation planning authority. The "Metro as RTPA" column refers to the agency's broad planning function—that is, Metro as the RTPA for L.A. County. Metro's additional role as the region's largest transit provider is captured in the "Transit Operators" column. LACDPW = L.A. County Department of Public Works. DOT = department of transportation.

implementing a recommendation, while *Required* means that the entity would need to support implementation efforts. Finally, *Optional* indicates that an agency's involvement might be helpful but not essential.

Although a large share of the recommendations will require coordination among multiple agencies or jurisdictions, developing the necessary political support among residents and elected officials will likely prove an even greater challenge. For this reason, we also examined complementary strategies for helping to build political consensus to support transportation-policy reforms in Los Angeles. We began by reviewing the scholarly literatures in planning and political science for relevant insights into the ingredients of successful collective action. We next spoke with local elected officials, agency staff, and leading transportation scholars and practitioners for further guidance. By integrating their advice with the general guidelines from the literature, we arrived at 10 complementary recommendations for helping to build the political consensus needed for many of the congestion-reduction strategies described in this book.

Note that one of the key ingredients in building political support is strong and persistent leadership, a role that can, in principle, be filled by either elected officials or community groups. We argue that the latter option offers the greater prospects for Los Angeles, as community leaders do not face the same constraints—such as election cycles and term limits—as elected officials do. With that in mind, the first six general recommendations would be relevant to community leaders who would like to assume a role in building support for the strategies recommended in this book. The final four recommendations focus on programmatic design considerations for specific congestion-reduction or revenue strategies and may be most helpful to elected officials and agency staff members in their efforts to plan and implement policies that can attract and maintain public support.

General Recommendations for Building Political Support

Form a coalition of community representatives to provide political leadership. The coalition would help to build political support and provide ongoing encouragement for elected leaders across L.A. County to pursue a coordinated and aggressive transportation agenda.

Include diverse interest groups when forming the community coalition. For the leadership of the community coalition to be viewed as legitimate, it must include the full range of affected parties. Examples include key industry groups; racial and ethnic groups; automotive, transit, and bicycle advocates; and environmental and social-justice advocates.

Develop agreement on the need for aggressive action to halt growth in congestion. To gain broad support for potentially controversial recommendations, it will be necessary to build agreement that L.A. traffic congestion has reached unacceptable levels, that it will likely worsen in future years, that existing remedies are ineffective, and that new strategies, including the use of pricing, are needed.

Define, broadly, the problems associated with congestion to help foster agreement on the need for action. Not everybody will agree that congestion by itself is such a severe problem that something must be done. Though no one enjoys sitting in traffic, some residents might feel that paying congestion tolls and paying higher prices for parking are even less desirable. Highlighting the full range of problems exacerbated by congestion—including economic, environmental, and social concerns—will help build greater support for the argument that aggressive action is needed.

Develop a compelling narrative of the benefits of action. Outlining the consequences of failing to act may be sufficient to motivate some, but offering a compelling vision of the benefits that will result from the comprehensive set of recommendations may persuade even more. Myers (2007) noted that effective leaders are also effective communicators who can weave together both majority and minority goals and preferences to create a community narrative that compels collective action. Myers further argued that an artful mix of future-oriented graphics, metaphors, and storytelling can bolster the success of this narrative.

Develop support for comprehensive programs rather than individual projects. The congestion-reduction strategy recommendations were selected to complement or reinforce one another. For instance, cordon tolls will reduce traffic congestion in crowded urban zones, and they will raise significant revenue for transportation investments. Tran-

sit improvements will provide viable options for those wishing to avoid the higher charges for driving during peak hours, and they will offer benefits to those who already rely on nonautomotive modes of travel. One-way street alignments will lead to improved travel speed and reduced intersection delays for automobiles, and they will introduce opportunities for creating bike lanes and bus-only lanes. As a package, the integrated strategy recommendations offer greater combined benefits, spread the costs more evenly, and offset many of the concerns that might apply to specific strategies in isolation.

Recommendations for the Design of Specific Strategies

Apply congestion-reduction strategies systematically. Certain strategies, such as one-way-street conversions and the prohibition of curb parking, may benefit motorists and transit users who travel in a particular traffic corridor but impose costs on local residents and merchants. To reduce concerns that certain groups are being asked to sacrifice for the benefit of others, we recommend implementing strategies systematically throughout the region (following, in some cases, initial demonstration projects to help familiarize residents with the benefits offered by some of the more innovative strategies). This will diffuse the costs and spread the benefits more broadly such that specific neighborhoods and retail districts will not feel that they have been singled out for unfair treatment.

Allocate pricing revenues to enlist support and mitigate equity concerns. Lack of organized support, on one hand, or spirited opposition, on the other, can prevent the implementation of pricing policies. Yet such strategies create a significant revenue stream, and choices about the allocation of the revenues can help to both build support and defuse opposition. For example, three possible allocations of the revenue resulting from cordon congestion tolls might include paying for public amenities within the charging zone, improving transit services in and around the charging zone, and partially subsidizing toll rates for lower-income motorists with demonstrated need (the tolls should not be entirely eliminated for lower-income drivers, as this would defeat the intent of using prices to manage peak-hour travel demand). Such allocations may help to enroll the support (or at least reduce the oppo-

sition) of local retailers and social-justice advocates, two of the groups most likely to oppose cordon tolls. Returning a portion of revenues to local merchants for public improvements has also been demonstrated as an effective strategy to build support for variable curbside parking rates (Shoup, 2005). Suitable protections should be instituted to ensure that that funds are expended only on specified purposes.

Allocate gas-tax revenues to build broad geographic support for the measure and ensure that revenues will be dedicated strictly to projects for improving mobility and reducing congestion. Local fuel taxes would likely be implemented at the county level. To build widespread support for this revenue measure, it is thus important to ensure that the benefits are broadly and fairly distributed. Echoing the importance of early stakeholder engagement, Hamideh et al. (2006) reported that local transportation-related ballot measures are more likely to be successful when the public has the opportunity to comment on the specific projects that they would most like to see funded. This may include transit improvements in denser urban areas and road improvements in more sparsely populated outlying areas. Strong protections should be provided against the diversion of funds to nontransportation uses, and recipients should be subject to maintenance-of-effort requirements to ensure that new revenues are treated as additions to current transportation expenditures, not substitutes for them.

Provide strong enforcement for strategies that involve pricing or driving restrictions. Recommended strategies that require strong enforcement include cordon congestion tolls, HOT lanes, variable curbside parking rates, curbside parking restrictions, and bus-only lanes. For strategies requiring that motorists either pay more or change their behavior, resentment will build if there is a perception that others are able to cheat the system (Short, 2004). Strong and consistent enforcement prevents this, and the resulting citation fees can help offset the costs of enforcement.

The Integration of Short-Term and Long-Term Strategies

This book, as noted, focuses on strategies that could be implemented and produce results within a few short years. Yet there are also compelling longer-term strategies that Los Angeles might pursue. Land-use reforms related to zoning, density, parking supply, and the mixing of uses may lead to development patterns less reliant on the automobile, for instance, while major infrastructure investments may help to improve transit options or reduce existing bottlenecks on the road network.

The shorter-term recommendations developed in this book, in addition to offering immediate benefits, should also complement longer-term strategies that Los Angeles might pursue. For instance, such strategies as cordon tolls, fuel taxes, and variable parking charges will produce significant and lasting revenue sources that can help to support future infrastructure investments. The implementation of pricing strategies to manage the demand for automotive travel, in turn, may help increase support for more compact development patterns clustering around high-capacity transit corridors and hubs.

Yet many of the strategies can be viewed as transitional as well. For instance, the recommendation to improve BRT includes the suggestion of implementing bus-only lanes on Wilshire Boulevard, one of the region's busiest transit corridors. Metro is currently evaluating the potential to construct a subway running the length of Wilshire, but, as yet, there is insufficient funding to pursue this option. As an interim step, developing bus-only lanes on Wilshire Boulevard would improve the speed and reliability of transit in the corridor at a much lower cost. It would also stimulate additional transit patronage, and this would reduce the level of subsidization ultimately required to build and operate a subway line under Wilshire Boulevard.

Many of the pricing recommendations in this book may also serve a transitional role. With recent technology developments, it is now possible to equip vehicles with on-board computers featuring Global Positioning System (GPS) receivers and digital road networks. As demonstrated in recent trials in Oregon and the Puget Sound region of Washington, this would enable the development of networkwide pricing applications with charges based on such factors as the number of

miles driven, the time and location of travel, and the characteristics (such as size, weight, and pollution emissions) of the vehicle driven (for discussion, see Sorensen and Taylor, 2006). If implemented, networkwide pricing applications could replace many of the shorter-term pricing recommendations discussed in this book, including fuel taxes, HOT lanes, and cordon tolls. Yet networkwide pricing represents an even more significant departure from current policies, and it will likely take time (and much debate) before the public is willing to consider this concept. In the interim, such options as HOT lanes and variable parking charges can help to familiarize L.A. residents with the benefits of pricing strategies, making it possible later to pursue more advanced forms of pricing.

Another issue to consider when evaluating policy options from the longer-term perspective—one that has become especially important of late—is the future trajectory of fuel prices. As of this writing, the cost of gas in Los Angeles is well over \$4 per gallon, and, in many locations, the price is closer to \$5. While many factors affect prices, continuing growth in the demand for oil in rapidly developing countries, such as China and India, suggest that the price may not drop significantly in the coming years and may well rise even further. At the same time, increasing concern about climate change is stimulating federal and state policy debates over how best to reduce greenhouse-gas emissions in the transport sector and elsewhere. The most promising strategies being considered, including carbon taxes and carbon cap-and-trade systems, would almost certainly lead to further increases in the price of gasoline and diesel.

Over the past six to nine months, as fuel prices have continued to climb and the economy has softened, the level of traffic congestion has declined on some routes in Los Angeles. Given that gas prices may remain at current levels or climb even higher in the coming years, it is reasonable to ask whether the recommendations in this book are really needed. We believe that they still offer significant value. To begin with, while congestion has eased, it has not evaporated, and delays on the busiest routes during peak hours are still severe. The economy, though struggling at the moment, will eventually recover, and the demand for automotive travel seems likely to increase over the longer term with

projected population growth and economic expansion. And should fuel prices remain high, automotive companies will likely offer greater numbers of fuel-efficient conventional vehicles as well as innovative options, such as plug-in hybrids and all-electric vehicles, to reduce the amount of fuel that drivers must purchase. Thus the prospects for continued increases in congestion in the longer term, in our view, appear considerable.

Even if higher fuel prices prove sufficient to dampen the demand for automotive travel in the longer term, however, the strategies recommended in this book would still serve a useful role. Efforts to improve nonautomotive travel alternatives, for instance, should take on even greater urgency. And while expensive measures for fine-tuning the operational efficiency of the existing road network (e.g., signal timing and control improvements) might receive less attention, options that simultaneously support faster and more reliable transit service—such as curb parking restrictions or one-way street alignments combined with the implementation of bus-only lanes—would also remain important.

Strategies that rely on pricing to manage peak-hour automotive travel present the most challenging question. If higher fuel prices lead to longer-term reductions in automotive travel, would pricing strategies still be helpful, or would they instead represent an additional burden on residents already struggling to pay their fuel bills? We can offer several reasons that it would still be useful to pursue the congestion pricing recommendations discussed in this book. To begin with, they would provide the necessary revenue for improving transportation alternatives in the region, and higher fuel prices could be expected to increase the demand for such options. In addition, as long as there are enough drivers to cause congestion on the busiest routes during peak hours, pricing strategies would still play a useful role in preventing the buildup of severe congestion. Finally, as higher fuel prices become more burdensome, pricing charges would actually become less burdensome. This is because the charges levied under such strategies as HOT lanes, cordon congestion tolls, and variable curb-parking rates are a direct function of demand—that is, they are set high enough to prevent congestion, but not higher. If higher fuel prices stimulate a reduction in automotive travel, the charges would decline correspondingly. And if

fuel prices became so severe that congestion dissipated, the charges would be zero.

In summary, the short-term strategies recommended in this book should complement longer-term strategies that Los Angeles might pursue, and they remain useful and appropriate in the face of sharply higher fuel prices.

Consensus Is Possible, with Benefits for All

The success or failure of congestion-reduction efforts in Los Angeles lies less in the realm of engineering and policy analysis and more in the political arena. The recommendations in this book are based on careful research and draw on evidence from successful implementations elsewhere, yet this is not the first publication to feature recommendations for managing peak-hour automotive travel through the mechanism of pricing. Implementing pricing strategies will be far more difficult than recommending them, and the political challenges will be compounded by the complexity of the transportation decisionmaking environment in L.A. County, in which cooperation among multiple agencies is required, and small but vocal opponents have ample democratic and legal options for derailing the process.

That said, there now appears to be a greater willingness among some elected officials in Los Angeles to consider pricing strategies as a fundamental ingredient for reducing congestion and raising revenue to improve transportation options in the region. As of this writing, the Metro Board of Commissioners has voted to accept federal funding under the U.S. Department of Transportation's Urban Partnership Agreement program to develop several HOT lanes in the county, while the City of Los Angeles has begun to install new parking-meter technology that will allow for the implementation of parking charges that vary with demand. While both of these are consistent with the recommendations in this book, they have not yet proceeded beyond the preliminary planning stages, and greater opposition may arise as plans move closer to implementation. This underscores the importance

of community leaders stepping in to help develop broader support for such measures.

Encouragingly, our analysis indicates that successful collective action is possible—with strong and persistent leadership, in a process that includes all interested parties from the start and ensures that all concerns receive due attention. Our analysis leads us to believe that the ends will justify the effort, as reducing congestion should help to improve quality of life, enhance economic competitiveness, reduce greenhouse-gas emissions, improve air quality in freeway-adjacent neighborhoods, and improve mobility for drivers and transit patrons alike.

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As always, any errors are the responsibility of the authors.

Abbreviations

AB	California Assembly Bill
ACF	advocacy-coalition framework
ACTA	Alameda Corridor Transportation Authority
ALS	area licensing scheme
APTA	American Public Transportation Association
AQMD	South Coast Air Quality Management District
ARB	California Air Resources Board
ATMS	advanced traffic-management system
ATSAC	Automated Traffic Surveillance and Control
AVI	automatic vehicle identification
AVL	automatic vehicle locator
AVR	average vehicle ridership
BART	Bay Area Rapid Transit
BRT	bus rapid transit
BRU	Bus Riders Union
BTA	Bicycle Transportation Account
BTHA	Business, Transportation and Housing Agency

CAA	Clean Air Act
CAC	community advisory committee
CAFE	corporate average fuel economy
Cal/EPA	California Environmental Protection Agency
Caltrans	California Department of Transportation
CBD	central business district
CCTV	closed-circuit television
CEQA	California Environmental Quality Act
CESA	California Endangered Species Act
CHP	California Highway Patrol
COG	council of governments
cpmsvl	conflicts per million squared vehicles per lane
CRA	Civil Rights Act
CTC	California Transportation Commission
CTR	Commute Trip Reduction
CWA	Clean Water Act
dB	decibel
DMV	department of motor vehicles
DOT	department of transportation
EPA	U.S. Environmental Protection Agency
ERP	electronic road pricing
ESA	Endangered Species Act
ETRP	employee trip-reduction plan
FHWA	Federal Highway Administration

FSP	Freeway Service Patrol
FTA	Federal Transit Administration
GCCOG	Gateway Cities Council of Governments
GDP	gross domestic product
GPS	Global Positioning System
HNC	Hoy No Circula [today, it does not circulate, or One Day Without a Car]
HOT	high-occupancy toll
HOV	high-occupancy vehicle
HOV 2+	requirement to have at least two people per vehicle
HOV 3+	requirement to have at least three people per vehicle
hp	horsepower
HTF	Highway Trust Fund
I-15	Interstate 15
I-110	Interstate 110
ICM	Integrated Corridor Management
IEN	information-exchange network
ISE	RAND Infrastructure, Safety, and Environment
ISP	Internet-service provider
ISTEA	Intermodal Surface Transportation Efficiency Act
IT	information technology
ITS	intelligent transportation system
kg	kilogram
km/h	kilometers per hour

L.A.	Los Angeles
LACDPW	Los Angeles County Department of Public Works
LADOT	City of Los Angeles Department of Transportation
lagging PPLT	protected/permissive left-turn phasing
LAX	Los Angeles International Airport
leading PPLT	permissive/protected left-turn phasing
m	meter
MCS	major-corridor study
Metro	Los Angeles County Metropolitan Transportation Authority
mph	miles per hour
MPO	metropolitan planning organization
MUTCD	<i>Manual on Uniform Traffic Control Devices</i>
NEPA	National Environmental Policy Act
NRDC	Natural Resources Defense Council
OBR	Operation Bottleneck Relief
PAYD	pay as you drive
PCH	Pacific Coast Highway
PeMS	Freeway Performance Measurement System
RABO	Residential Area–Based Offices
RIITS	Regional Integration of Intelligent Transportation Systems
RTP	regional transportation plan
RTPA	regional transportation planning authority
SB	senate bill

SBCCOG	South Bay Cities Council of Governments
SCAG	Southern California Association of Governments
SGVCOG	San Gabriel Valley Council of Governments
SOV	single-occupant vehicle
SR	state route
STIP	California State Transportation Improvement Program
SUV	sport-utility vehicle
SWARM	systemwide adaptive ramp metering
TAP	transit-access pass
TAZ	traffic-analysis zone
TDM	transportation demand management
TEU	20-foot-equivalent unit
TMC	traffic-management center
TSM	transportation system management
TST	Transportation, Space, and Technology
TTI	Texas Transportation Institute
UCLA	University of California, Los Angeles
USDOT	U.S. Department of Transportation
V/C	volume to capacity
VMS	variable-message sign
VMT	vehicle miles traveled
WCCOG	Westside Cities Council of Governments
WMATA	Washington Metropolitan Area Transit Authority

Introduction

The purpose of this study was to evaluate and recommend strategies for reducing congestion in and around Los Angeles¹ that could be implemented and produce results in a short time frame, defined as a period of about five years or less. We focus on options available to public-sector agencies operating in Los Angeles (L.A.) County, though some of the measures may require the involvement of private participants as well. We are especially interested in strategies that might be pursued by some of the larger public agencies in the region, such as the City of Los Angeles Department of Transportation (LADOT), the L.A. County Metropolitan Transportation Authority (Metro), and District 7 of the California Department of Transportation (Caltrans), but many strategies considered would also be relevant for smaller municipal transportation departments and transit operators.

We also pay special attention to strategies suitable for densely populated urban areas, where congestion is often most severe. While some of the strategies we consider would be applicable in both urban and suburban areas, we do not include strategies targeted specifically at less dense suburban settings. The principal geographic scope of the study might thus be described as the city of Los Angeles and other densely populated cities in L.A. County. In addition, we focus primarily on strategies related to passenger travel; while some of the strategies considered would also apply to freight trucks, the scope of the project

¹ Note that, in this book, we often use the general term *Los Angeles* to refer to the region as a whole. Where greater jurisdictional specificity is required, we refer to either Los Angeles County or the City of Los Angeles.

did not allow for the inclusion of strategies focusing primarily on the goods-movement sector.

The strategies considered in this book fall into two broad categories: supply-side measures designed to enhance the effective capacity or efficiency of the region's transportation network and demand-side measures intended to manage or reduce automotive travel during the most congested periods. Though many of the available options hold promise for reducing congestion, some will require additional revenue, while others are likely to encounter political opposition. We employ a threefold approach to address such implementation obstacles. First, we recommend several congestion-reduction strategies that also generate revenue, and the additional funding can help support other strategy investments. Second, our recommendations include complementary measures intended to help offset potential equity issues and political concerns where they arise. Third, we develop several general guidelines to support effective political consensus-building in the context of a complex political environment characterized by numerous agencies and stakeholders with competing issues and agendas.

Motivation for This Book

Ask a cross-section of L.A. residents about their main sources of daily frustration and you will likely find that traffic congestion appears high on their lists. For better or worse, traffic congestion has become an increasingly prevalent by-product of urban living, one that besets almost all major cities in the United States and abroad. While there are other international cities, such as Bangkok, Jakarta, and Lagos, in which traffic congestion is even more severe (Taylor, 2002), Los Angeles maintains a reputation for having the worst traffic conditions in the United States. According to the Texas Transportation Institute (TTI), which develops the most widely cited congestion statistics for large metropolitan areas in the country, greater Los Angeles consistently leads the nation in such metrics as annual hours of congestion delay per traveler, total vehicle hours of congestion delay, and total economic costs of congestion delay. And with continued expansion in the

population and economy, the severity of congestion in Los Angeles has grown worse from one year to the next in a fairly consistent manner (Schrank and Lomax, 2007).

That said, in just the past six to nine months, as fuel prices have surged and the economy has weakened, there is evidence to suggest that congestion delays on some parts of the road network in Los Angeles have been reduced to a modest degree. Yet it is reasonable to assume that the economy will strengthen again at some point and that travelers will increasingly purchase more fuel-efficient cars should gas prices remain high. Assuming continued growth in population and the economy in the coming decades, it thus seems likely that traffic congestion, absent policy intervention, will sooner or later resume its upward trajectory.

This would be unfortunate. Beyond annoyance and frustration on the part of individual travelers, traffic congestion contributes to a range of pressing social problems. Time wasted in congested traffic, depending on the purpose of travel, detracts from quality of life and economic vitality. Congested travel also results in wasted fuel and increased emissions. Because crowded freeways often pass through lower-income neighborhoods, the additional emissions of air pollutants, such as carbon monoxide, nitrogen oxides, and particulate matter, raise important environmental-justice concerns (Deka, 2004). At the same time, heightened awareness of the threats posed by human-induced climate change have stimulated increasing concern over vehicular emissions of greenhouse gases, such as carbon dioxide. Finally, traffic congestion may contribute to a higher rate of vehicle collisions.²

With all these undesirable effects, one might wonder why society has not taken more-aggressive steps to curb congestion. For many residents in the region, severe traffic has been an ongoing source of aggravation and furthermore imposes a range of significant economic, social, and environmental costs. Yet before deciding to pursue immediate and possibly drastic measures to eliminate the problem at any cost, it is important to recognize that congestion is linked with many desirable

² However, in conditions of severe congestion, when traffic speeds are low, crashes that do occur are likely to be less severe than they are at higher speeds.

characteristics, such as a strong economy and a vibrant urban environment (Downs, 2004; Taylor, 2002). This helps to explain, for instance, why dynamic and appealing cities, such as New York and Paris, are subject to chronic traffic congestion. We also find that, during periods of economic downturn, such as in San Francisco following the dot-com bust in the early 2000s or in Los Angeles following the downturn in defense spending in the early 1990s, the level of traffic congestion diminishes. (We are also witnessing such a downturn at the present time, though high fuel prices are playing a role as well.) While it may be desirable to reduce congestion, care should certainly be taken to ensure that the strategies invoked do not simultaneously undermine the desirable urban characteristics that give rise to congestion in the first place.

This need not be a problem. Transportation economists have demonstrated that there are strategies for reducing congestion that will simultaneously improve our collective well-being. As described previously, the act of driving a vehicle creates a range of environmental and social costs, such as harmful emissions and additional congestion delays for other travelers. Yet when we choose to drive, we are not forced to pay for these costs, which economists describe as *externalities* (Downs, 2004). Rather, they must be borne by other members of society, such as drivers traveling in our traffic wake or residents living alongside the freeways on which we travel. Because we are not charged for many of the costs associated with driving, our society tends to over-consume road space—that is, we often make trips for which the total costs, including the external costs imposed on others, exceed the benefits we receive. When the costs exceed the benefits—regardless of their distribution—we are worse off as a society.

It stands to reason, therefore, that it should be possible to find ways of reducing congestion that will make society better off, improving both quality of life and economic competitiveness. By definition, finding ways to discourage trips for which the social costs exceed the private benefits will serve this end. There may be cost-effective strategies for improving the efficiency of existing transportation networks as well. Given both the social and personal costs and frustrations stem-

ming from heavily congested travel conditions, it behooves us to seek such solutions.

Unfortunately, the most compelling strategies at our disposal are unlikely to be devoid of controversy. Traffic congestion, though clearly growing worse before the recent run-up in fuel prices, is not a new phenomenon, and policymakers have grappled with the issue for centuries. Most of the easy solutions to congestion—those that do not cost too much or engender significant political resistance—have already been implemented. There are, in fact, unexploited strategies available that would be very effective in reducing congestion, but most of these would require that we either (1) pay more to travel, through indirect taxes or direct user fees, or (2) change our behavior by traveling less, traveling at different times, traveling on different routes, or relying on alternative modes of transportation. For any such strategy, there will likely be one or more segments of society—neighborhood associations, industry groups, environmental coalitions, or advocates for lower-income and other underrepresented populations—who feel that the strategy would make their constituencies worse off, even if society is better off as a whole. The potential for organized and spirited stakeholder opposition is thus high, and, in the highly fragmented political-decisionmaking context of Los Angeles, such opposition is often sufficient to prevent implementation of policy options that would otherwise promote net improvements in public welfare.

On the other hand, there are complementary measures that can help mitigate the costs imposed on certain groups and thus defuse the potential for sustained political opposition. There are also useful planning practices related to stakeholder outreach and consensus building that can help to align support for congestion-reduction strategies that might be expected, at the outset, to generate a significant level of contention. Because many strategies discussed in this book are both novel (from Los Angeles's perspective) and inherently controversial, we devote significant attention to options for mitigating the concerns of specific stakeholder groups and building political consensus and willpower in a fragmented decisionmaking environment. We also consider strategies for equitably raising revenues to help fund some of the congestion-reduction measures that might prove useful in Los Angeles.

Our Approach

To support the development of short-term congestion-reduction recommendations for Los Angeles, our study addressed these key tasks:

- Develop a conceptual understanding of congestion.
- Characterize congestion in Los Angeles.
- Diagnose congestion in Los Angeles.
- Identify potential congestion-reduction strategies.
- Assess potential congestion-reduction strategies.
- Develop congestion-reduction recommendations for the area.
- Develop complementary consensus-building recommendations.

Developing a Conceptual Understanding of Congestion

Traffic congestion, a longstanding urban challenge, has received considerable attention from transportation and planning researchers over the years. This has led to a wealth of information about the causes and behavior of congestion as well as the efficacy of alternative approaches to reducing congestion. We begin by reviewing the available literature and summarizing key lessons to inform the discussion of potential congestion-reduction strategies for Los Angeles.

Characterizing Congestion in Los Angeles

We next analyze both aggregate and detailed traffic data to characterize congestion in Los Angeles, examining current conditions as well as recent trends. The results underscore the severity of the problem, which may, in turn, lead to a greater willingness on the part of officials and residents to consider promising but controversial options for reducing traffic. The analysis also highlights areas in the county where the level of congestion is most extreme. This information may prove useful in prioritizing future traffic-mitigation efforts. Finally, the assessment yields insight about whether specific strategies would be useful or even feasible for different facilities, in different corridors, or around different activity centers.

Diagnosing Congestion in Los Angeles

After characterizing congestion in Los Angeles, we next examine the question of why it appears to be more severe than in other large cities across the country. Our analysis reveals that the intensity of traffic in the region stems, directly or indirectly, from high aggregate population density at the regional scale and is further complicated by polycentric land-use patterns. This leads to important insights regarding the congestion-reduction strategies likely to be most effective in the region.

Identifying Potential Congestion-Reduction Strategies

To identify potential congestion-reduction strategies for Los Angeles, we review the transportation research literature, examine prior studies and proposals for Los Angeles, and explore innovative approaches currently being pursued in other major cities. We then pare the initial list of strategies to a smaller set for further analysis, focusing on those that (1) can be implemented and produce results in the short term, defined as a period of approximately five years or less;³ (2) can be implemented (or strongly influenced) based on policy decisions made by local governments; (3) are suitable for densely populated urban areas like Los Angeles; and (4) focus on passenger travel (as opposed to goods movement).⁴ Available alternatives satisfying each of these criteria include options for improving the efficiency of the existing road network; reducing the demand for peak-hour automotive travel through incentives, regulations, or pricing; and improving alternative modes of

³ Broadly speaking, the short-term criterion rules out major capacity expansions, such as new highways or rail lines, as well as most land-use reforms. In the case of major capacity investments, planning and construction activities will almost certainly require more than five years. While land use–policy reforms could be implemented more quickly, their effects would unfold over a much longer time frame as the urban landscape slowly evolves.

⁴ With the Ports of Los Angeles and Long Beach, truck travel accounts for a significant share of road use—and congestion—in the Los Angeles region. There are likely to be promising congestion-reduction measures that would apply specifically to goods-movement activities, but it was beyond the financial scope of our study to include such measures. On the other hand, many of the congestion-reduction strategies that would be useful for passenger travel would apply to truck traffic as well.

travel, such as bus transit, bicycling, and walking. In total, we identify 28 strategies for further examination.

Assessing Potential Congestion-Reduction Strategies

We next assess the advantages and disadvantages of these alternative strategies in the context of Los Angeles, considering such factors as cost and revenue implications, effectiveness in reducing congestion over the short and longer terms, effects on other transportation goals, effects on other social goals, likely implementation obstacles, and current level of implementation in Los Angeles. In assessing each strategy, we review evidence from the research literature as well as from local and national media sources. We also interview staff members from many of the agencies responsible for transportation planning in Los Angeles to understand the current level of implementation for various strategies throughout the region and to learn more about options that are currently being considered or planned.

Developing Congestion-Reduction Recommendations for Los Angeles

The principal goal of the study was to develop a specific set of congestion reduction–strategy recommendations for Los Angeles. Drawing on earlier stages of the analysis, we first construct a guiding policy framework for Los Angeles consisting of three complementary elements: (1) employing pricing strategies (such as tolls, parking fees, and fuel taxes) to manage the demand for peak-hour automotive travel and raise additional revenue; (2) improving alternative transportation options to enhance traveler choice and mitigate equity concerns that may arise with certain forms of pricing; and (3) implementing additional strategies to use the current road system more efficiently, but with a shift in focus from moving vehicles to moving passengers. With this framework in place, we then examine the available strategy options and, based on their relative strengths and limitations, select those that best support one or more elements of the framework. In total, we develop 10 primary recommendations worthy of immediate pursuit, along with three contingent recommendations that either require further research or depend on how certain events unfold in the coming months and

years. For each of the recommendations, we also suggest immediate and follow-on implementation steps.

Developing Complementary Consensus-Building Recommendations

Many of our congestion reduction–strategy recommendations are likely to face opposition. To bolster the prospects for successful implementation, it is thus useful to develop complementary strategies for building political consensus. The challenges associated with overcoming obstacles and developing support in a complex political environment are unique neither to traffic congestion nor to Los Angeles, and the conditions that contribute to successful collective action have long been of central interest to political scientists and planning theorists. Drawing on the relevant theoretical literature as well as practical examples, we first distill several guiding principles for successful collection action. From these, we develop a set of specific political recommendations to support more-effective transportation decisionmaking in the L.A. context.

Organization of This Book

Chapter Two examines the phenomenon of congestion at the conceptual level, offering accumulated wisdom from the research literature on how it occurs, why it has been getting worse, and what may be required if we wish to reduce or eliminate it. Next, Chapter Three presents our characterization of congestion in Los Angeles, including current conditions and recent trends. Chapter Four then examines some of the underlying causes that contribute to the severity of congestion in Los Angeles relative to other U.S. cities. In Chapter Five, we turn our attention to possible solutions, examining the full spectrum of options and arriving at a set of 28 potential short-term strategies for further consideration. We also summarize our assessment of the relative advantages and limitations of these options. Drawing on this analysis, in Chapter Six, we develop a set of 10 primary and three contingent strategy recommendations intended to reduce congestion, raise revenue, and improve transportation alternatives in the region. Though the strate-

gies are combined in such a manner as to mitigate potential equity issues and other stakeholder concerns that might arise, it is nonetheless likely that certain options will engender political controversy. For this reason, we consider, in Chapter Seven, complementary strategies for building political consensus. Chapter Eight addresses the question of whether the strategies recommended in this book would still be appropriate if gas prices remain high or rise even further (for the most part, they would) and then offers closing commentary on the challenges and opportunities of transportation policy in Los Angeles. Appendix A provides a discussion of the methodology for assessing the strengths and weaknesses of alternative congestion-reduction strategies; the detailed assessments for the strategies are then provided in Appendixes B1 through B28. Appendix C reviews the roles of agencies at different levels of government in transportation policy and planning in Los Angeles, while Appendix D provides background discussion of the relevant theories for successful political consensus building.

A Primer on Congestion

Many of us are familiar with traffic congestion because we must deal with it on a daily basis. During peak hours, the number of cars outstrips the capacity of the road network, and thus we waste many hours each year enduring stop-and-go travel conditions on the region's highway and arterial networks. Yet the phenomenon of congestion is deceptively complex, and subtle characteristics of travel behavior and traffic-flow patterns may surprise even the veteran rush-hour commuter.

This chapter begins with a brief historical perspective on congestion, demonstrating that the problem, in one form or another, is almost as old as cities themselves. That said, congestion has, without question, intensified in the past century with the advent of the automobile, especially in recent years (notwithstanding the results of higher fuel prices and a weakening economy in the past six to nine months, as discussed in the preceding chapter). We therefore consider some of the key underlying trends that have exacerbated congestion—most notably, continued growth in the demand for passenger travel and, to an even greater extent, truck travel, set against significant reductions in investments in new road capacity. The trajectory of these underlying trends suggests that traffic congestion on our highways and arterial network will, as current economic challenges are resolved, continue to worsen in the coming decades, absent significant policy intervention.

Traffic congestion has received considerable attention among academics, analysts, and policymakers over much of the past century, and, as a result, there is much that we do know about the phenomenon. There is also growing evidence that we can effectively reduce congestion

if we pursue certain options. This chapter concludes with a distillation of several key insights based on the work of transportation researchers and analysts in the past several decades. Some of these afford greater understanding of the nature of congestion itself, while others provide guidance on the most promising approaches for reducing it.

What emerges from the discussions in this chapter is at once encouraging and discouraging. On one hand, congestion is not insurmountable, and several approaches offer the potential to halt, or even reverse, the current increase in congested travel conditions. On the other hand, these approaches will require more concerted political willpower than the county has been able to summon to date, and congestion will almost certainly worsen in the coming decades should it fail to implement appropriate policy reforms.

Congestion Is a Long-Standing Problem

Congestion is a by-product of concentrated activity and thus it should come as no surprise that cities—which exist to facilitate the concentration of activity—have wrestled with congestion, in one form or another, throughout modern history. At the height of ancient Rome, Caesar attempted to control congestion by banning transport carts from the streets between sunrise and dusk (Carcopino, 1940). More recently, when delegates from around the world gathered in New York City for the world's first international planning conference in 1898, attention centered not on questions of housing, land use, economic development, or infrastructure. Rather, attendees were most concerned with problems stemming from the growing concentration of horses and carriages in the city, including both traffic congestion and a contemporary form of pollution: manure (Morris, 2007).

With the introduction and rapid growth of automotive travel in the 20th century, the problem of urban congestion escalated rapidly. In Los Angeles, traffic congestion has been an ongoing concern for many decades. At various points in the city's history, frustrations about traffic congestion have fueled public debates, inspired innovative proposals, and ultimately resulted in public-policy actions. An initiative

by business interests in the early 1920s led to the installation of the city's first traffic signals, the regulation of on-street parking, dramatic improvements in public transit, and a plan for extending the network of major east-west boulevards and highways. As continued growth in travel overwhelmed these earlier improvements, Los Angeles began to plan and build new freeways in the 1940s and 1950s and, in the 1970s, launched efforts to add rail rapid transit back into the regional mix of options. Advances in the 1980s and 1990s included extensive deployment of freeway-ramp meters, reserved lanes for high-occupancy vehicles (HOVs), and computerized traffic-signal control to help improve traffic flow. Most recently, the Metro Rapid and Orange Line bus rapid transit (BRT) systems have offered important advances in the quality of transportation options available in the region.

In each of these cases, growth in congestion motivated the consideration and adoption of alternative approaches to reduce or control traffic—approaches that proved successful in the short term, until continued growth in population and economy added even more travelers to the system. Today, Los Angeles finds itself in much the same predicament.

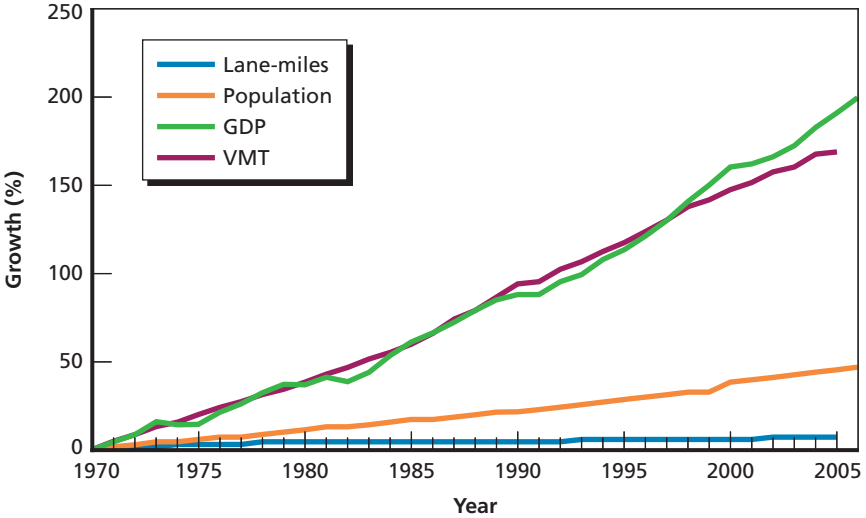
Absent Intervention, Congestion Will Likely Worsen

If congestion is already severe, the bad news is that it will likely grow worse in the coming decades, given current trends in the underlying factors that contribute to congestion. Fundamentally, congestion results from an imbalance between the supply of roadways and the demand for automotive travel during peak hours (Downs, 2004). This imbalance, as illustrated in Figure 2.1, has been growing over the past several decades across the country.

Travel Demand Continues to Rise

The data in Figure 2.1 indicate that the total number of estimated lane-miles throughout the United States has grown only slightly—just over 7 percent—since 1970, while the number of vehicle-miles traveled (VMT), has increased by about 170 percent. The population has

Figure 2.1
Growth in Lane-Miles, Population, Gross Domestic Product, and Vehicle-Miles Traveled in the United States Since 1970



SOURCES: BEA (2008); BTS (2007a, 2008); U.S. Census Bureau (2007).

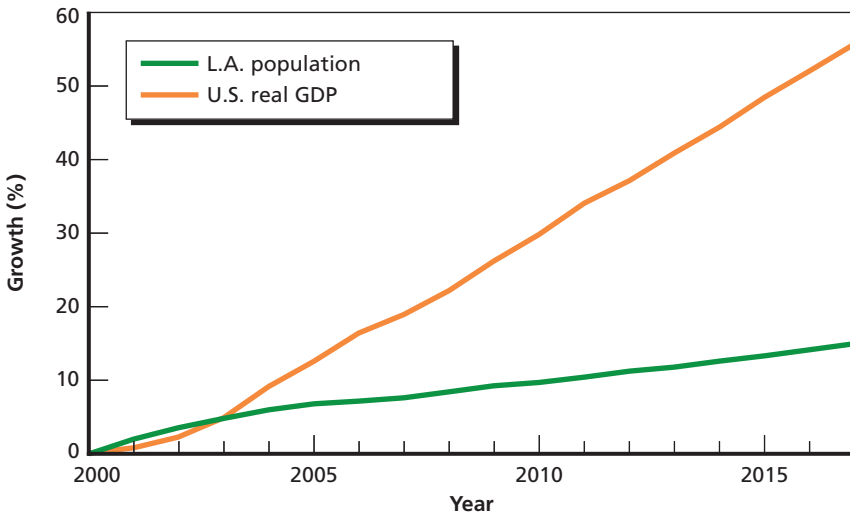
NOTE: GDP = gross domestic product.

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grown as well, by almost 50 percent, but the increase in demand for travel has far surpassed population growth. Indeed, growth in VMT appears to track most closely with growth in the economy as measured by GDP. This is consistent with the logic that people with more money can afford to buy more cars and travel to more places (Downs, 2004).

If future travel demand continues to track growth in GDP, or even just growth in the population, and if new capacity is built at the same sluggish pace as it has been in the past several decades, congestion will almost certainly worsen, likely to a significant degree. Figure 2.2 shows actual and forecasted growth for the population of L.A. County and national GDP between 2000 and 2017. Over this period, it is expected that the population in L.A. County will increase by about 15 percent, while GDP for the economy as a whole will rise by more than 50 percent. If past trends hold, this will lead to a considerable rise in aggregate demand for automotive travel.

Figure 2.2
Recent and Forecasted Growth in Population and Gross Domestic Product



SOURCES: California Department of Finance (2007); CBO (2008).

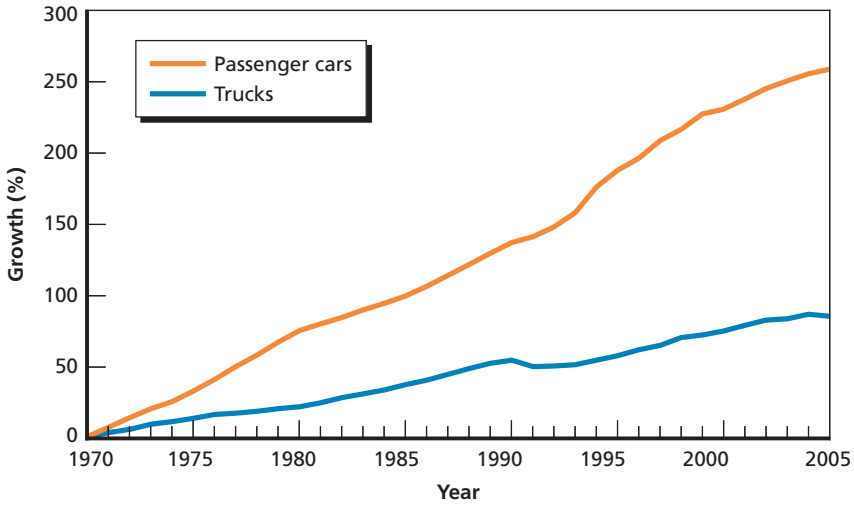
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Truck Travel Is Rising Even More Rapidly

While growth in the general level of travel over the past several decades has been substantial, the increase in trucking has been greater still. International trade has skyrocketed with globalization, and we now move far more goods by truck than in the past. This trend is especially pronounced in the L.A. region, where the Ports of Los Angeles and Long Beach collectively handle about 43 percent of all container shipments entering the United States (SCAG, 2005). Thus, L.A. freeways and major arterials are increasingly crowded not just with cars but with trucks as well. Figure 2.3 compares the growth in truck travel with that of passenger-vehicle travel since 1970. Over this period, while VMT for passenger vehicles has grown by about 85 percent, the growth in truck-miles has exceeded 250 percent.

Notwithstanding current challenges posed by a weakening economy and higher fuel prices, globalization shows no signs of slowing over the longer term, and the rapid rise in truck traffic is expected to

Figure 2.3
Growth in Passenger-Vehicle Versus Truck Vehicle-Miles Traveled in the United States



SOURCE: BTS (2007a).

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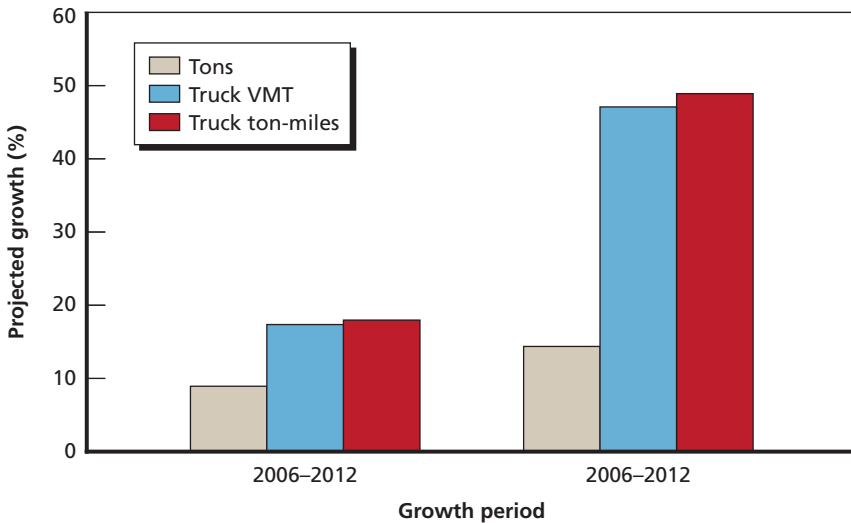
continue in the coming decades. As shown in Figure 2.4, the number of truck-miles nationwide is forecast to increase by almost 20 percent between 2006 and 2012 and by almost 50 percent between 2006 and 2018.

Locally, the increase in truck travel may be even more dramatic. The Southern California Association of Governments (SCAG) has projected that the number of 20-foot-equivalent-unit (TEU) containers moving through the Ports of Los Angeles and Long Beach each year—about 13.2 million as of 2005—will increase to about 36 million TEUs (a 270-percent increase) by 2020 and to almost 45 million TEUs (a 340-percent increase) by 2030 (SCAG, 2005). Absent significant expansion in rail capacity, trucks will need to carry much of the growth in container shipments in and out of the region.

Significant Road Expansion Is Unlikely

If we hope to avoid a significant increase in the level of congestion resulting from additional demand for both passenger and truck travel

Figure 2.4
Projected Growth in Truck Travel



SOURCE: ATA (2007).

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in future years by accelerating the pace of new road construction, we will almost certainly be met with disappointment. It is widely recognized that freeways and other major roads are disruptive to existing neighborhoods, causing an increase in air pollution, noise pollution, and visual blight (Deka, 2004). Local residents are thus likely to unite in opposition to proposals to build new or expand existing roads in their neighborhoods, as they have done since the “freeway revolts” beginning in the 1970s (Taylor, 1995).

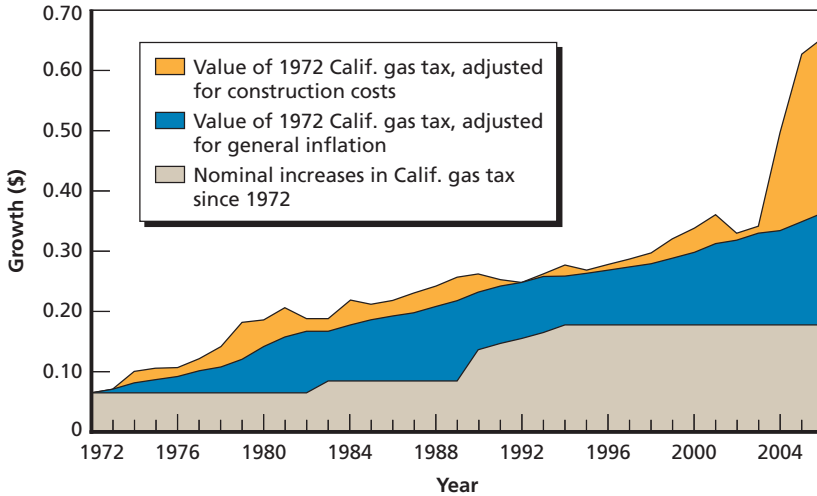
Even if the county overcomes intense political opposition to significant urban road expansion, it must still confront difficult fiscal realities. In California, as in other states, the majority of revenue for freeways and major roads—more than 60 percent—comes from motor-fuel excise taxes levied at the state and federal levels (TRB, 2006). Unfortunately, motor-fuel excise taxes are burdened by structural and political limitations, and their effectiveness in generating sufficient revenues for needed transportation investments has been waning in recent decades. Motor-fuel excise taxes are levied on a cents-per-gallon basis

(as opposed to a percentage of the purchase price), and their value will thus erode with inflation unless offset by periodic rate adjustments enacted by elected officials or through direct ballot initiative. Since the 1970s, as the level of antitax fervor has grown, elected leaders have become increasingly wary of proposing hikes to existing motor-fuel taxes, and, as a result, this important source of road revenues has stagnated (Sorensen and Taylor, 2005a). Federal excise fuel taxes (currently \$0.184 per gallon of gasoline and \$0.244 per gallon of diesel) have not been raised since 1993, while excise fuel taxes in California (currently \$0.18 per gallon for both gasoline and diesel) have not increased since 1994 (Sorensen, 2006).

While the inflation-adjusted value of fuel-tax revenues has declined, the cost of transportation projects—including land for right-of-way, labor, and construction materials—has been increasing even more rapidly than the general rate of inflation (Wachs, 2003a). This relationship is illustrated in Figure 2.5, which compares the nominal increase in California's motor-fuel excise taxes since 1972 with the growth in general inflation and in the cost of highway construction in California during the same period. In 1972, the California motor-fuel excise tax was \$0.07 per gallon of gasoline. Since then, it has been raised several times, most recently in 1994, and now stands at \$0.18 per gallon. Over the same period, however, the value of \$0.07 has grown with inflation to more than \$0.36. In other words, the county would need to double the current rate of motor-fuel taxes just to keep pace with the general rate of inflation. When compared with growth in the costs of construction, the challenge is even more pronounced. To achieve an equivalent purchasing power with respect to construction inputs, the gas tax would need to be raised to about \$0.65 per gallon, more than triple its current rate. In short, the gas tax no longer buys what it used to.

In addition to inflation, improvements in fuel economy—though beneficial in other respects—also contribute to the degradation of fuel-tax revenues. Since the mid-1970s, when Congress passed the first corporate average fuel economy (CAFE) legislation specifying that automobile manufacturers must achieve certain mileage standards, the average fuel economy of vehicles in this country has increased by

Figure 2.5
Growth in the California Gas Tax Versus General Inflation and Highway Construction Costs



SOURCES: California Department of Industrial Relations (2007); Caltrans (undated, 2008).

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almost two-thirds, rising from about 13.5 miles per gallon in the early 1970s to a little over 22 miles per gallon today (based on data from BTS, 2007b, 2007c). In the past decade, as the popularity of sport-utility vehicles (SUVs) and light-duty trucks has grown, improvements in fuel economy have tailed off to some degree, though there has still been a slight rise as older cars are replaced with newer, more efficient ones. Yet with recent concerns about climate change and the security implications of continued dependence on oil from other countries, legislators in Washington appear poised to pass sharp increases to current CAFE standards. Moreover, with gasoline prices now well over \$4.00 per gallon, consumers are increasingly demanding more-efficient vehicles. In short, the average fuel economy of vehicles in this country may well begin to climb more rapidly in the coming decade.

From the perspective of transportation revenues, the main drawback of improved fuel economy is that cars are able to travel farther on each gallon of gas. Because motor-fuel excise taxes are levied on a per-gallon basis, this means that state and federal governments collect

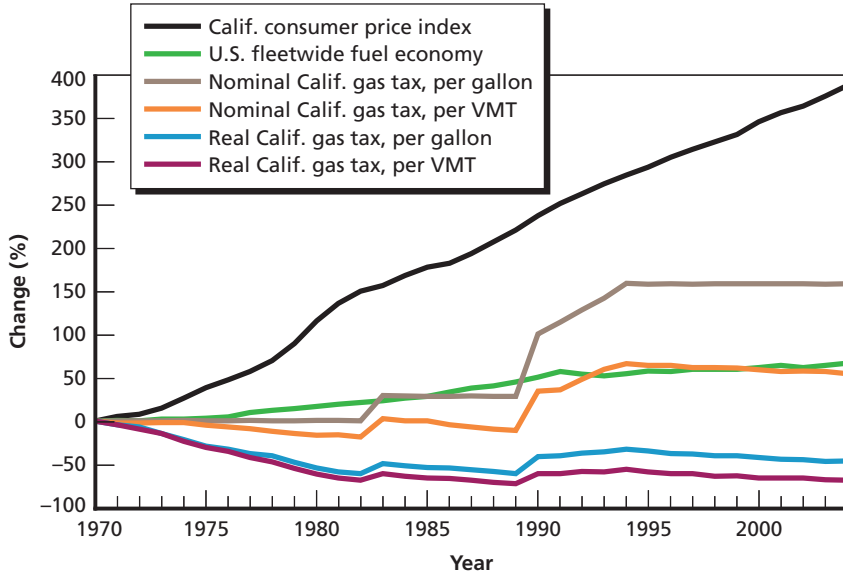
less revenue for each mile of travel (Wachs, 2003a). This is problematic, given that the need to maintain and expand the road system is a function not of the gallons of gas we burn but rather of the number of miles we drive. Thus legislators should ideally enact periodic gas-tax hikes to account for improved fuel economy as well inflation, but they have not done so in recent years.

With the reluctance of elected officials to raise motor-fuel excise taxes, the combined effects of inflation and improved fuel economy have significantly retarded the funding stream yielded by this important transportation-revenue source, especially in terms of real (inflation-adjusted) revenue per mile of travel. Figure 2.6 illustrates this point.

As the data in Figure 2.6 show, the cumulative rate of inflation has been almost 400 percent since 1970, while average fuel economy has increased by about 65 percent. The nominal California gas tax in cents per gallon has increased by about 160 percent—from \$0.07 in 1970 to \$0.18 today—but this has not kept pace with the combined effects of inflation and fuel economy. Thus we see that the change in real revenue per VMT has declined by more than two-thirds since 1970. In other words, we would need to triple the current motor-fuel excise taxes in California to account for both inflation and improved fuel economy over the past four decades. To keep up with inflation in highway construction costs, as suggested by the data shown in Figure 2.3, the increase would need to be even greater.

Despite numerous studies pointing to the need to raise current fuel taxes based on such considerations (e.g., ATRI, 2007; Brown, 2001; Pisarski, 2005; Wachs, 2003a), the current political climate in Washington and in Sacramento, combined with mounting concerns over the state of the economy and rising fuel prices, make it unlikely that legislators will soon consider such significant fuel-tax increases. For the near future, at least, to keep pace with growing automotive demand, the county will probably not have at its disposal sufficient transportation revenues from these traditional sources to contemplate major road-network expansions or significant transit enhancements.

Figure 2.6
Combined Effects of Inflation and Fuel-Economy Improvements on Real California Gas-Tax Revenues, per Mile of Travel



SOURCES: BTS (2007a, 2007b); California Department of Industrial Relations (2007); Caltrans (undated).

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Confronting Congestion Is a Challenging Proposition

As the preceding sections have demonstrated, road congestion is a problem that has confronted Los Angeles and other urban areas for many decades, has been growing worse in recent years, and, in all likelihood, will continue to do so, given the current trajectories of relevant trends. It is not surprising, then, that planners have experimented with a variety of approaches for curbing congestion and continue to develop novel proposals. Researchers have paid close attention to these efforts, and, as a result, we know much about the causes, behavior, and potential solutions for congestion. This section distills a collection of useful insights that can help inform development of congestion-reduction strategies for Los Angeles.

Driving Is Not an Irrational Choice

The automobile is undeniably convenient. And in many areas where land-use patterns have evolved around the automobile, it is virtually essential. As discussed in Chapter One, automotive travel is also underpriced, in the sense that drivers are not required to bear the social costs associated with their travel decisions—costs that include increased congestion, air pollution, and greenhouse-gas emissions (Parry, Walls, and Harrington, 2007). In addition, many federal, state, and local public policies encourage, either directly or indirectly, increased reliance on the automobile. The Internal Revenue Service, for example, treats employer-paid parking as a tax-free benefit, while many local zoning provisions establish minimum parking requirements for new development that implicitly assume that parking will be provided for free (Shoup, 2005). As a result of these factors, in most U.S. cities, driving is by far the dominant mode of travel (Pisarski, 2006). Given the combined incentives of convenience and underpricing, it is unlikely that voluntary traffic-reduction measures, such as appeals to carpool or travel at off-peak hours, will yield significant results over the long term. To alter the calculus of travel decisions, it may be more effective to either increase the cost of driving or significantly enhance the speed and convenience of alternative modes.

Congestion Is a By-Product of Convenient Scheduling

If we could divide our travel equally across the 24 hours of the day, congestion would be much less of an issue. Travel patterns flow from activity patterns, though, and, as a society, we tend to schedule our activities to maximize both convenience and efficiency (Downs, 2004). For instance, most businesses operate during the same hours to facilitate meetings and transactions. School days, meanwhile, often begin at roughly the same hours, making it easier for parents to drop off their kids on the way to work. We thus see significant congestion during the morning and afternoon peak hours, while traffic flows more smoothly at other times. To reduce congestion, we could endeavor to stagger our activity schedules to a greater degree, but this would, in turn, make it more difficult to arrange our personal and professional activities and obligations. There is an inherent trade-off, then, between the conve-

nience of traveling to our activities and the convenience of our activity schedules themselves.

Commuting Is Just Part of the Problem

Because morning and evening rush hours coincide with the times when most workers travel to and from work, it is easy to assume that commuters bear primary responsibility for congestion on the roadways. Yet commuting constitutes a surprisingly small share of total vehicle travel nationally, representing just under 15 percent of total person trips and just over 18 percent of total person-miles of travel (Pisarski, 2006). During peak hours, the share of commuters on the road is higher, but nonwork trips still account for a significant percentage of the vehicles contributing to congestion. This is not to suggest that employer strategies to reduce the number of commuters who drive to work alone are not worthwhile; such programs can, in fact, be quite effective (Giuliano, Hwang, and Wachs, 1993). But it is also important to consider strategies that encompass noncommuters as well. Because nonwork trips are often discretionary, they may be more easily altered or shifted than work-related trips in response to strategies aimed at managing the demand for automotive travel during peak hours.

Nonrecurrent Congestion Is a Major Concern

The term *nonrecurrent congestion* is used to describe traffic delays caused by random, temporary, intermittent, or periodic occurrences, such as vehicle breakdowns, crashes, severe weather, special events, or temporary lane closures for construction or maintenance activities. Such occurrences account for a significant percentage of total delays on the road network. Recent evidence suggests that traffic incidents (including disabled vehicles and crashes), for example, may be responsible for about 60 percent of peak-hour congestion in major metropolitan areas (Downs, 2004). The implication is that strategies that can help to reduce nonrecurrent congestion should be extremely valuable in mitigating traffic delays as a whole. Possible strategies in this vein include enhanced incident detection, response, and clearing capabilities; the prohibition of construction activities during peak travel periods; and

reprioritization of the arterial traffic-signal system to more rapidly clear traffic departing from special events.

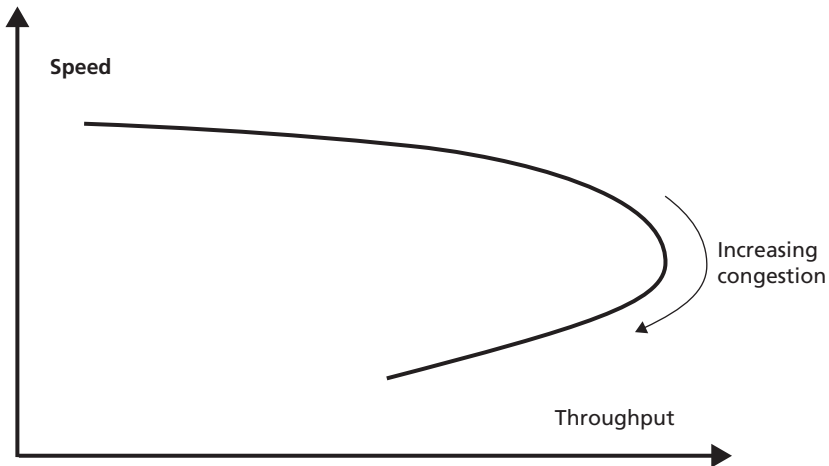
Congestion Is a Nonlinear Phenomenon

The relationship between travel speeds and vehicle throughput (or flow volume, measured as the number of cars that pass by a certain point each hour) is nonlinear (Homburger et al., 2007). That is, the effects of adding a few more cars onto the road depend on the number of cars already using the road. When just a few cars occupy the road, drivers can travel at free-flowing speed. As additional cars join in, the space between each vehicle diminishes but speed remains unimpeded and total flow increases. With yet more cars, vehicles start to slow down a bit, but throughput still rises. At a certain point, however, when too many cars are trying to use the roadway at the same time, congestion begins to occur, and use of the roadway suddenly becomes much less efficient (on the highways, this tipping point tends to occur at around 35 to 40 miles per hour, or mph). Not only does speed decrease, but flow volume decreases as well, and throughput continues to decline as congestion grows more severe. In other words, once a certain tipping point is reached, the outcome of adding more cars to the road is to reduce the effective capacity of the road, further exacerbating congestion. This nonlinear relationship between speed and throughput, often described as a *backward-bending curve*, is illustrated in Figure 2.7.

The behavior illustrated in Figure 2.7 can be interpreted as either discouraging or encouraging. On one hand, given that congestion in Los Angeles is already severe—that is, it often progresses beyond the backward-bending point in the curve—even small increases in travel demand could result in significantly worse congestion than the area currently faces. On the other hand, if the county actively pursues steps to manage travel demand in the peak hours, shifting even a small percentage of drivers to other modes, other routes, or other times of travel could achieve significant reductions in congestion.¹ The good news, then, is that, to cut congestion-related delays by 50 percent, it is not

¹ This is why we see, for instance, that, on certain governmental or religious holidays, when only a small portion of the workforce is able to take the day off, the level of congestion none-

Figure 2.7
Nonlinear Speed Versus Throughput Relationship



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necessary to reduce the number of vehicles on the road by 50 percent. Indeed, if the number of peak-hour trips could go down by even 5 or 10 percent, the effects would likely be dramatic.

Congestion Grows in Space and Time

Severe congestion is a deterrent to additional driving, leading many to plan their trips either along different routes or at different times of the day. As a result, continued growth in automotive travel will not necessarily lead to significantly worse traffic at the busiest times of day and in the most congested areas. Rather, what may occur is a slow but steady increase in the number of congested travel hours each day and the percentage of the road network routinely subject to congestion delays. In other words, congestion is apt to grow in space and time.

theless declines markedly. It also helps to explain why slight decreases in driving in response to increased fuel prices in the past six to nine months have resulted in noticeable reductions in congestion delays.

Congestion Solves a More Fundamental Problem

Most people would justifiably view congestion as a problem, not a solution. Beyond the question of aggravation and inconvenience, congestion results in wasted fuel, wasted time, and excessive emissions of local air pollutants and greenhouse gases. From a different perspective, though, congestion can be viewed as a solution, albeit an unpleasant one (Downs, 2004). The deeper problem we face is that, at the present price of travel,² the demand for driving exceeds the road network's available capacity during peak hours. This suggests several possible responses. On one hand, either by building more roads or by using existing ones more efficiently through such approaches as traffic-signal timing and control, boosting supply could solve this problem. Alternatively, area planners could strive to manage the demand for driving in the peak hours. This might be achieved, for instance, by encouraging drivers to form carpools or enhancing other modal options such that more people would choose to ride transit, bike, or walk. More-explicit measures to ration demand, such as forbidding certain drivers from using the roads during peak hours or imposing tolls for peak-hour travel, could help as well. Finally, drivers could simply wait in line for their turn to use the roads, in which case congestion will balance supply and demand for us. In practice, L.A. County pursues many of the solutions outlined here to some extent but often relies on congestion as the default "solution."

There Are No Silver-Bullet Solutions

If we were to define the ideal solution to congestion as one that is both effective and easy to implement—that is, not costing too much nor raising significant political opposition—there would be few options at our disposal (Giuliano and Hanson, 2004). Because the problem of congestion has plagued cities for decades, the majority of effective, inexpensive, and uncontroversial strategies have already been employed. Of the remaining options, many offer only modest additional benefits, while those with greater potential to reduce traffic are either very expensive

² Including auto ownership or leasing costs, insurance, fuel, and fuel taxes, but not including externalities, such as the costs of congestion and emissions imposed on society as a whole.

or likely to encounter significant political resistance. This presents a dilemma. Many people would like to see a reduction in congestion, but few appear willing to pay more money or change their travel behavior to achieve this end. The most effective strategies available, unfortunately, will require either one or the other (or both). This leaves two broad options: *Either continue to implement a wide range of less expensive and less controversial measures that offer modest benefits in the hope that their combined effects will be significant, or strive to overcome financial and political obstacles in order to pursue the options that would appear to hold the greatest promise for reducing congestion.*

Many Strategies Fail to Achieve Longer-Term Reductions in Peak-Hour Congestion

Downs (2004) noted that many people already make a conscious decision to travel at other times of day, on different routes, or by different modes—even if this involves some inconvenience—so as to avoid congested travel conditions. If strategies are employed to improve the flow of traffic on crowded thoroughfares, however, travelers will soon notice the reduction in congestion and return to their preferred travel patterns. In other words, there will be a *triple convergence* on the newly freed capacity—as travelers shift from other times of day, from other routes, or from other modes—thus eroding the initial peak-hour congestion-reduction effects. Over the longer term, general increases in automotive travel demand resulting from economic expansion and population growth will further undermine the effectiveness of many strategies.

Taken together, triple convergence and general growth in automotive travel limit the long-term sustainability of most approaches to reducing peak-hour traffic in the most congested areas. For instance, we often see that, when new lanes are added to a freeway, flow may improve for a short while, but the facility usually returns to former levels of congestion in just a few years. The same occurs with improvements to other modes, such as a new subway line or faster bus service. While such improvements can encourage some travelers to switch from driving to transit, others will soon converge upon the road capacity vacated by those travelers. Triple convergence can undermine both voluntary and regulatory demand-reduction approaches as well. If employers are

forced to offer incentives to encourage their employees not to drive to work alone, for example, any reductions in peak-hour automotive commute trips might soon be offset by a rise in the presence of other drivers engaged in nonwork travel.

Note that the preceding arguments are not meant to imply that strategies subject to the effects of triple convergence or longer-term growth in travel demand do not provide other benefits. For instance, if an improvement leads drivers to converge on newly freed capacity from other routes, times, or modes of travel, then congestion on those other routes, at those other times, or on those other modes should lessen (even if congestion persists on the most crowded routes at the busiest times of day). In addition, strategies that boost effective road capacity will, by definition, facilitate an overall increase in mobility, while strategies that improve transportation alternatives afford greater traveler choice and provide better options for those who do not drive. Though triple convergence and longer-term growth in the demand for automotive travel may undermine the ability of such strategies to ease peak-hour traffic congestion along the busiest routes, the strategies may still offer other benefits that make them worth pursuing.

Only Pricing Strategies Lead to Sustainable Congestion Reductions

The only strategies resistant to the effects of triple convergence involve the use of pricing to manage the demand for peak-hour automotive travel (Downs, 2004). Often referred to as *congestion pricing*, this includes charging higher tolls to drive during peak hours (Sorensen and Taylor, 2006) and charging higher prices to park in the most convenient curb spaces at the busiest times of day (Shoup, 2005). The main reason that triple convergence does not erode the congestion-reduction effects of pricing is that the same peak-hour charges that encourage some to change their travel patterns to avoid incurring additional costs also deter others from converging on the freed capacity. In other words, congestion pricing is the only approach that can reduce congestion without inducing additional automotive travel demand.

Pricing also remains effective over the longer term in the face of generally increasing demand, provided that the prices charged are allowed to increase with demand. Managing demand through the

application of pricing is still a relatively novel approach, but it has been pursued with increasing frequency in many cities throughout the world over the past decade—in part because it has proven effective in reducing congestion and in part because it also raises needed transportation revenue. Evidence to date suggests that congestion pricing has been quite effective wherever it has been employed (Sorensen and Taylor, 2006). The primary challenge, as discussed later, is that most proposals to employ pricing raise equity concerns (some legitimate, others less so) and can be expected to meet with considerable political opposition.

Pricing Strategies Can Enable More Travel During Peak Hours

This point is subtle and seems somewhat paradoxical. By increasing the cost of driving, one would think that *fewer* travelers would choose to drive during the peak hours. As noted earlier, however, congestion is a nonlinear phenomenon, and the capacity of the road network is severely degraded during periods of significant congestion. Pricing strategies lead to a reduction in congestion, and this, in turn, allows lanes to carry *more* vehicles per hour.³ The net effect of pricing, then, may not be to reduce peak-hour automotive travel at the aggregate level but rather to moderate the flow of vehicles in peak hours to prevent the buildup of congested conditions that would otherwise degrade lane capacity.⁴ We thus can describe many pricing strategies as *managing*, as opposed to *reducing*, peak-hour automotive travel demand.

How Transportation Is Financed Influences Congestion

Related to the observation that pricing strategies are effective in reducing congestion is the more general point that the mechanisms used to

³ On the State Route (SR) 91 facility in Orange County, for example, which includes four free lanes and two priced lanes moving in each direction, the priced lanes carry roughly double the number of vehicles per hour per lane at free-flowing travel speeds as the heavily congested free lanes do during peak travel hours (Obenberger, 2004).

⁴ In fact, on the Interstate 15 (I-15) high-occupancy toll (HOT) lanes in San Diego, a well-known example of congestion tolling, the toll rates are updated as often as every six minutes based on current traffic conditions to prevent congestion from arising (prices are displayed on large message signs in advance of the facility's entry point so that drivers can choose whether they wish to pay the current toll).

fund transportation can exert a strong influence on travel behavior. At a broad level, transportation-revenue sources can be divided into two main categories: general revenues and user fees. General revenues, such as income taxes, property taxes, business taxes, sales taxes, and general obligation bonds,⁵ are unrelated to use of the transportation system, whereas user fees, including gas taxes, tolls, and parking charges, are explicitly linked to transportation. User fees offer two key advantages over general revenues for funding transportation investments. First, with user fees, the amount one pays varies in rough proportion to the amount one drives. This aligns costs with benefits, which can be viewed as promoting greater equity in transportation finance (Wachs, 2003b). Second, user fees increase the cost of driving, and this acts as a direct financial incentive to alter travel patterns, leading, in turn, to reduced congestion.⁶ Certain user fees, such as peak-hour tolls and variable parking charges, are specifically designed to help manage automotive travel at the busiest times of day. Others, such as fuel taxes, encourage general reductions in driving at all times.

Despite the advantages of user fees, local governments often rely on general revenue sources, such as sales taxes and general obligation bonds, to raise funds for transportation (Goldman and Wachs, 2003). Voters in L.A. County, for example, have approved Propositions A (passed in 1980) and C (passed in 1990), two 0.5-percent sales taxes dedicated to local transportation projects. By implementing user fees

⁵ Bonds to be repaid from a government's general revenue fund.

⁶ Note that user fees can be further subdivided into *fixed-cost* and *marginal-cost* fees. With fixed-cost user fees, users must pay a fixed amount on a periodic basis, but the amount paid is independent of the amount traveled. Examples include license and registration fees. Fixed-cost user fees can still influence travel behavior to some extent—for instance, higher registration fees may encourage some individuals to own fewer cars, and this in turn should lead to less total driving. With fixed-cost fees, however, once the fee has been paid, there is no additional motivation to alter travel decisions. Marginal-cost user fees, in contrast, are linked to the amount one drives and, in some cases, to the time and location of travel. Examples include fuel taxes, tolls, and parking charges. With such fees, each additional unit of travel increases the amount owed, and this provides a strong and continuous incentive for drivers to forgo their least productive trips. Marginal-cost user fees are thus more effective than fixed-cost fees in managing the demand for automotive travel.

instead, Los Angeles could raise additional revenue and simultaneously ease congestion, reducing, in turn, the need for new capacity investments. Many of the pricing strategies discussed in this book, if implemented, would represent a step in this direction.

Increasing Population Density Argues for Alternative Travel Modes

Contrary to the widely held image of Los Angeles as a poster child for sprawling development, the region is, in fact, quite densely populated. Though downtown Los Angeles is not as dense as, say, Manhattan, its surrounding suburbs are far denser than those of other cities (Manville and Shoup, 2005). Thus a more apt description of urban form in Los Angeles may be *dense sprawl* (Eidlin, 2005). This bodes poorly for the prospects of unfettered automobility in the region, as density and congestion are highly correlated (Manville and Shoup, 2005). On the other hand, higher levels of density provide more opportunities to use alternative travel modes, such as walking, biking, and transit. Trip origins and destinations are often much closer together in dense environments, making it possible to complete a larger percentage of trips without relying on the automobile. In addition, density provides a sufficiently concentrated base of potential transit patrons to justify (based on expected ridership) investments in fast and efficient transit options, such as subways and dedicated bus lanes.

Regardless of the steps taken to combat congestion, investing in improved travel alternatives—and especially enhanced transit options—will provide considerable benefits in the coming years. Should Los Angeles choose to employ pricing strategies to reduce peak-hour automotive travel, better transit options will provide alternatives for those unable or unwilling to pay peak-hour tolls. If the region fails to pursue aggressive demand-reduction strategies, on the other hand, congestion will almost certainly worsen as the population and economy grow. In this case, better transit services will at least provide an alternative for travelers who would prefer to avoid driving on congested roads.

Summary

Congestion, as we have discussed in this chapter, is not a new phenomenon. It has, however, intensified in recent years, and the underlying trends suggest that it will continue to worsen, absent policy intervention. Population and income—two important drivers of travel demand—are both expected to increase considerably in the coming decades. Investment in the transportation system, meanwhile, has stagnated, and there is no reason to believe that this will soon change. Motor-fuel excise taxes constitute a significant share of transportation revenues at both the state and federal levels. Levied on a per-gallon basis, these taxes must be raised periodically to offset the combined effects of inflation and improved fuel economy. Legislators have grown increasingly unwilling to take on this politically unpopular task, however, and, as a result, the purchasing power of fuel-tax revenues has declined precipitously in the past 20 or 30 years. We thus find that the gap between needed transportation maintenance and expansion projects on one hand and available revenues on the other is widening.

That said, promising options are still available. Because congestion is a long-standing urban challenge, it has received considerable attention from researchers and policymakers alike, and we know much about the causes of and potential cures for congestion. Key insights relevant to the task of developing short-term congestion-reduction strategy recommendations include the following:

- Commuting, contrary to popular belief, constitutes a relatively small share (less than 20 percent) of all travel. While the proportion may be higher during peak travel hours, it is still important to consider strategies that apply not only to commuters but to drivers engaged in personal trips as well.
- Nonrecurrent congestion—caused by random or intermittent events, such as traffic accidents, breakdowns, or special events—may be responsible for as much as 60 percent of congestion delays in major cities. Developing effective strategies to reduce nonrecurrent congestion should therefore prove extremely valuable.

- Traffic congestion is a nonlinear phenomenon. The practical import of this observation is that small reductions in the demand for travel during peak hours may result in dramatic improvements in traffic flow. This is encouraging, as it is much easier to devise strategies capable of reducing travel demand by 5 or 10 percent than it would be to achieve reductions of, say, 25 or 50 percent.
- Because severe congestion is itself a deterrent to additional driving, drivers will often seek to travel by other routes or at other times of day. As result, continued growth in travel may have little effect on congestion on the busiest routes at the busiest times of day; rather, congested travel conditions will tend to spread in space and time.
- The underlying cause of traffic delays is an imbalance between supply and demand. Congestion—that is, making drivers wait their turn to use available road space—represents one way of balancing supply and demand, but there are other alternatives. It is possible to boost supply, either by building new roads or by using the existing system more efficiently. Another alternative is to reduce the demand for travel by implementing voluntary, regulatory, or pricing strategies. A third option is to provide more-compelling alternatives to the automobile, including better transit, biking, and pedestrian facilities.
- Because congestion has plagued cities for many years, most of the easy solutions—those that are inexpensive and uncontroversial—have already been applied. While options remain, many of these will require that we either (1) pay more money to drive or (2) change our travel behavior. As a result, the most promising strategies are likely to face considerable political obstacles.
- A phenomenon referred to as *triple convergence* erodes the effectiveness of many congestion-reduction strategies. When traffic conditions on a facility are improved in the peak hours, additional travelers will converge on that facility—from other times, other routes, or other modes—thereby slowly offsetting the initial traffic improvements. Longer-term growth in travel demand resulting from population increases and economic expansion will further limit or undermine the benefits of many strategies.

- Only strategies that rely on pricing to manage peak-hour automotive-travel demand, such as congestion tolls, are resistant to the effects of triple convergence and remain effective in the face of longer-term growth in demand. Unfortunately, such strategies are also among the most likely to generate significant political controversy.
- Pricing strategies also lead to more-efficient use of existing capacity. Thus, paradoxically, the imposition of pricing can enable more peak-hour journeys while reducing congestion.
- The mechanisms used to fund transportation investments can play an important role in reducing congestion. User fees—including tolls, gas taxes, and parking fees—raise the cost of driving. Depending on the specific structure of the fees, this provides a tangible and ongoing financial incentive that helps to either reduce the overall demand for driving or manage the demand for driving during peak hours. User fees thus generate revenue while reducing the need for new capacity investments.
- Increasing urban density stimulates additional congestion—and Los Angeles is very dense at the regional scale. This argues for the provision of improved transportation alternatives, such as faster transit services in the region. If Los Angeles addresses the long-term growth in congestion through pricing, such alternatives will provide options for those who wish to avoid paying higher tolls and parking charges for traveling in the peak hours. Should the region fail to address the long-term growth in congestion in a meaningful way, such alternatives will instead provide options for those who wish to avoid traveling on the increasingly crowded highways and arterial streets.

Characterizing Congestion in Los Angeles

The intent of this chapter is to characterize the scope and severity of congestion in Los Angeles, including current conditions and recent trends. The analysis shows that congestion in Los Angeles is considerable and has been increasing fairly steadily over time (although, as noted in Chapter Two, the recent surge in fuel prices combined with an ailing economy have led to modest reductions in congestion delays in the past six to nine months). Quantifying the severity of congestion in Los Angeles may help build political consensus about the need for effective policy intervention. In addition, characterizing the spatial variation in congestion across the county may offer useful insights as to whether certain congestion-reduction strategies might be helpful in some areas or corridors but not in others.

Congestion in Los Angeles Could Be Worse

A primary thrust of this chapter is to demonstrate the severity and scope of congestion in Los Angeles. Yet it is worth noting that there are many places around the world—especially in developing countries—where congestion is a far greater problem (Downs, 2004; Taylor, 2002).

Though Los Angeles leads the nation in many congestion metrics, traffic congestion in the region would be much worse if not for the concerted efforts of planners, engineers, and law-enforcement officers working at the city, county, regional, and state levels. Agencies in Los Angeles have developed a suite of advanced tools and practices for helping to manage congestion and provide additional travel

choices to local residents, including sophisticated ramp metering and signal-synchronization systems, a highly coordinated freeway incident-management system, new heavy- and light-rail transit lines, and a successful BRT system. Without such efforts, as noted in a recent TTI study (Schrank and Lomax, 2007), congestion in the L.A. region would likely be far worse than it is today.

That said, congestion in Los Angeles can still be characterized as severe and has worsened progressively over the years. Our examination of the available evidence shows the following:

- Los Angeles leads the nation in urban congestion.
- Statistically, congestion in the region has risen in recent years.
- Congestion on the highway system is pervasive throughout the county.
- Congestion on the arterials is especially intense on the Westside.
- Truck traffic is concentrated around the ports, around downtown Los Angeles, and on many of the region's freeways.

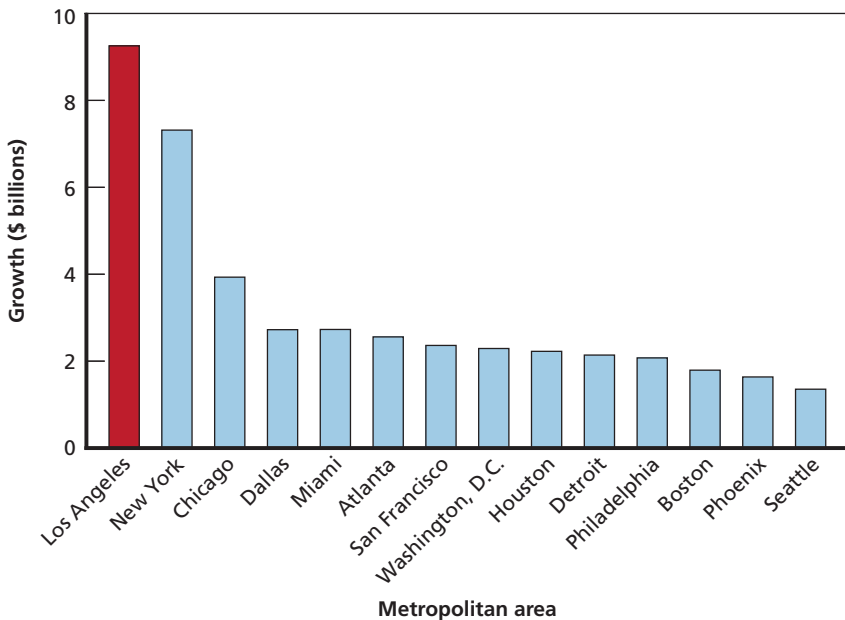
Los Angeles Leads the Nation in Congestion

There are many ways that one might go about measuring congestion. How long does the rush hour last? What percentage of the road network experiences congestion? How many hours each year does a traveler spend stuck in congested traffic? How slowly does the traffic move, on average, during the peak period? By many of the metrics, one might devise, Los Angeles appears to lead the nation in terms of the extent and severity of its traffic congestion.

Since 1982, TTI has been publishing an annual urban-mobility report that estimates various congestion statistics for large metropolitan areas across the country (Schrank and Lomax, 2007). Though transportation researchers have critiqued some of the embedded assumptions and methodologies, TTI nonetheless provides the most comprehensive comparisons of congestion in U.S. cities currently available, and its annual results routinely garner significant attention in local and national press.

One of the key statistics developed by TTI is the annual cost of congestion in each metropolitan area covered by the study. This is determined by estimating the total hours of delay due to congestion for all travelers in a region over the course of the year and then multiplying that figure by (1) an estimate of the value of time and (2) an estimate of the cost of the excess fuel burned as a result of traveling at suboptimal speed. Figure 3.1 shows TTI's most recent estimates for the cost of congestion in the 14 largest metropolitan areas in the country.¹ As the figure shows, the L.A. region leads all other major urban areas in terms of total annual congestion-related costs. New York is a close second, while all other regions exhibit considerably lower totals.

Figure 3.1
Annual Cost of Congestion in Major U.S. Metropolitan Areas



SOURCE: Schrank and Lomax (2007).

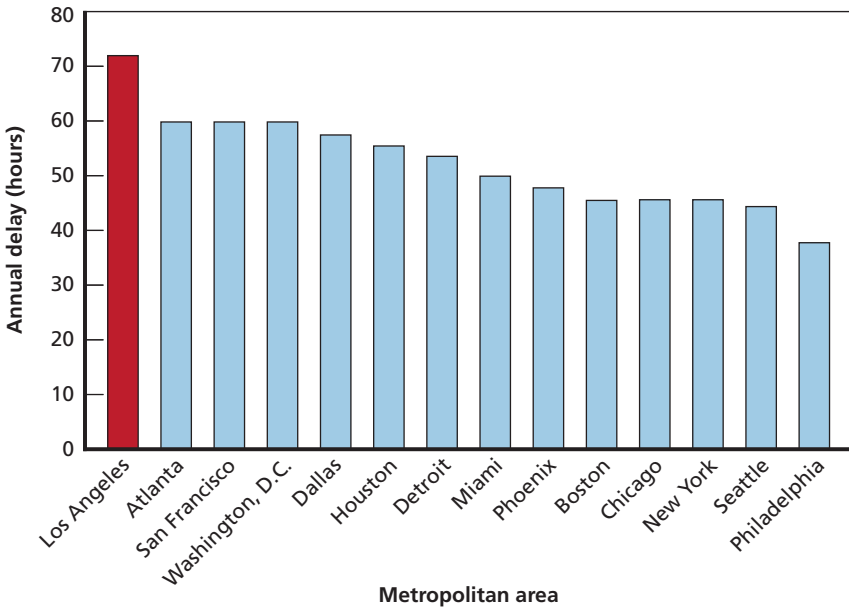
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¹ Note that we have listed just the primary city in the different metropolitan regions covered by the study, but the metropolitan boundaries typically extend far beyond city limits.

In reviewing the data in Figure 3.1, one might expect that one of the reasons Los Angeles leads the nation in the total cost of congestion is simply that the population of the greater L.A. region is larger than that of most other metropolitan areas. As it happens, TTI also estimates a statistic for the average annual hours of congestion delay per peak-period traveler. As shown in Figure 3.2, Los Angeles ranks first in this rating as well. Note that TTI does not report per capita (as opposed to per-peak-period traveler) delays or congestion costs; if one divides TTI’s estimates for total congestion cost and total population, however, Los Angeles leads all other major metropolitan areas in per capita costs.

In fact, the L.A. region leads, or is near the top, for most of the congestion-related statistics developed by TTI (Schrank and Lomax,

Figure 3.2
Annual Hours of Congestion Delay per Peak-Hour Traveler in Major U.S. Metropolitan Areas



SOURCE: Schrank and Lomax (2007).

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2007). For example, Los Angeles ranks first in total annual hours of delay for all travelers (490 million), total annual gallons of wasted fuel for all travelers (384 million), and average annual gallons of wasted fuel per peak-period traveler (57 gallons).² Los Angeles also has the highest *travel-time index* (the ratio of peak-period travel time to travel time during free-flowing conditions) among U.S. metropolitan areas.

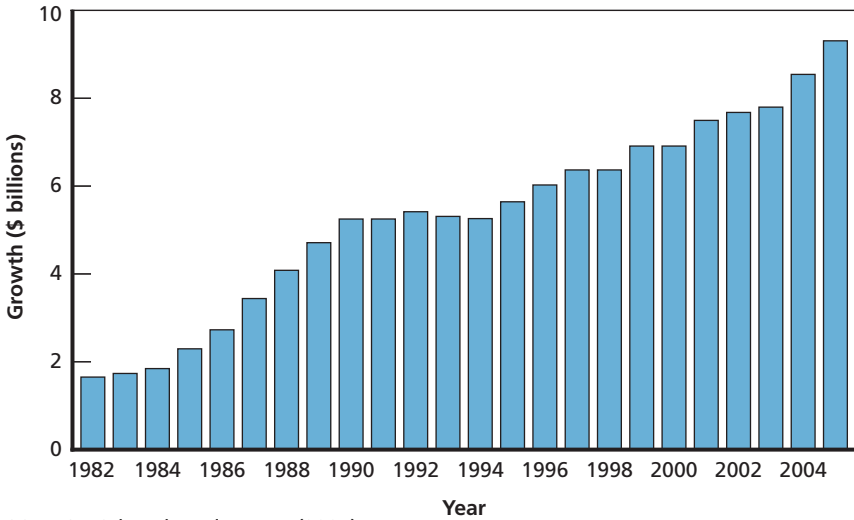
Congestion in Los Angeles Continues to Worsen

Though congestion has recently declined to a modest degree in response to surging fuel prices and flagging economic conditions, the longer-term trend shows a fairly persistent rise in congestion delays over the past several decades. TTI has been tracking traffic statistics for major metropolitan areas since 1982, making it possible to evaluate the trajectory of congestion indicators over a period of more than 25 years. In Los Angeles, as in most major U.S. cities, the numbers are heading in an undesirable direction. For example, Figure 3.3 shows the annual growth in TTI's estimate for the total congestion costs (inflation adjusted) for the L.A. region during this period. Except for a brief respite during the recession of the early 1990s, this figure has marched steadily upward, growing from a little under \$2 billion in 1982 to more than \$9 billion as of 2007.

Illustrating a similar trend, Figure 3.4 shows the annual growth in congested travel conditions, including the percentage of peak-hour VMT subject to congestion delays and the percentage of the road network that is congested during the peak travel hours. Both have increased significantly since 1982, though their trajectories appear to have flattened out to some extent in recent years. (Incidentally, we suspect that the recent flattening of the trends shown in this figure may be an artifact of the sampling procedure used by TTI. Later in this chapter, in Figure 3.8, we present data indicating that both the spatial spread and

² Note that TTI defines *wasted fuel* as the difference between the number of gallons that would be burned in uncongested travel conditions and the number of gallons burned during congested travel.

Figure 3.3
Growth in the Annual Cost of Congestion in Los Angeles



SOURCE: Schrank and Lomax (2007).

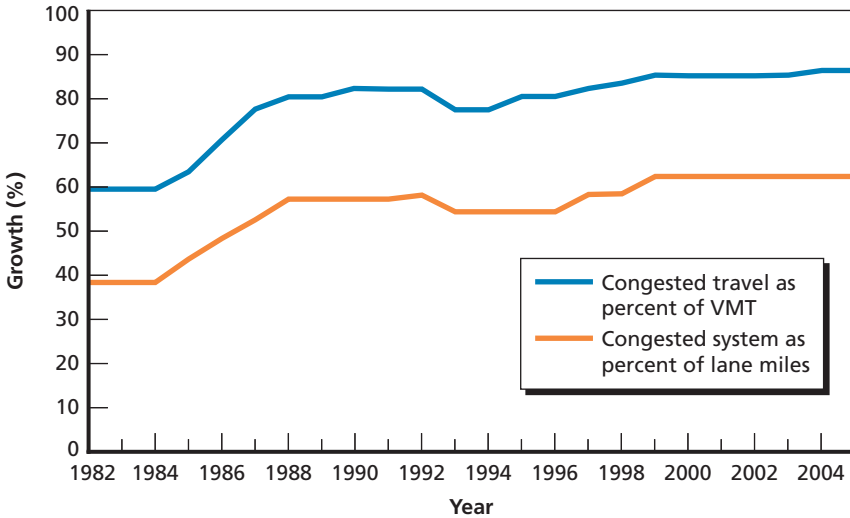
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temporal duration of congested travel conditions on the freeway network in Los Angeles increased considerably between 2001 and 2006.)

Congestion on the Highways Is Severe Throughout Los Angeles

After reviewing the aggregate congestion statistics provided by TTI, we examined more closely the current conditions on the freeways and arterial network in the county. For the freeways, we relied on empirical volume and speed data available from the Freeway Performance Measurement System (PeMS) database developed by transportation engineers from the University of California, Berkeley, using information collected by Caltrans sensors embedded throughout the freeway network. The data available in PeMS are both extensive and highly detailed, enabling researchers to examine vehicle speed and flow rates on specific highway links at five-minute intervals dating back to 2001.

Figure 3.4
Growth in Congested Travel Conditions in Los Angeles



SOURCE: Schrank and Lomax (2007).

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By aggregating PeMS data over time and across different links in the network, it is possible to develop a series of detailed maps that accurately portray current conditions and recent changes in the level of congestion on the Los Angeles freeway system. The map in Figure 3.5 shows the average number of hours per day, for weekdays in 2006,³ during which the travel speed on each link in the freeway network averaged less than 35 mph.⁴

Figure 3.5 shows that there are a few corridors in which congestion appears to be especially severe, such as the I-5 near the Orange County border and U.S. Route 101 just northwest of downtown Los Angeles. The general story that emerges from the map, however, is that significant congestion is spread throughout the freeway network, with

³ The most recent year for which a full set of PeMS data was available during the study.

⁴ For convenience, we have averaged the data across both directions of flow. For instance, a link with four hours of average travel speed less than 35 mph in one direction and six hours in the other direction would be averaged to five hours.

Figure 3.5
Average Hours per Day During Which Speed Averaged Less Than 35 mph in General-Purpose Lanes, 2006 Weekdays



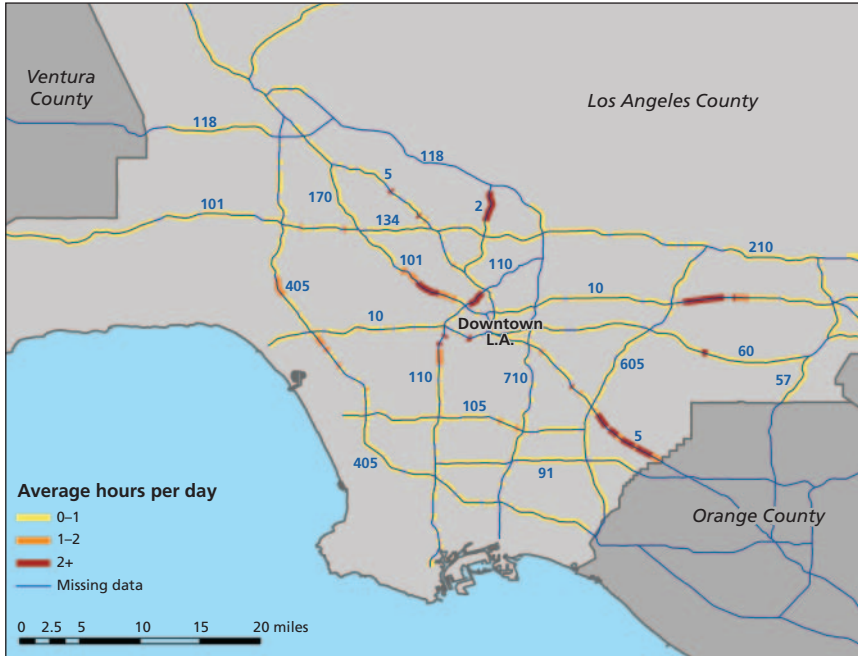
SOURCE: PeMS (undated).

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many links experiencing four or more hours per day of travel speeds averaging less than 35 mph. Note also that the numbers we have mapped represent averages over the course of an entire year; on any given day, the number of hours of congested travel might be considerably higher.

Unfortunately, travelers in Los Angeles receive little reprieve when traveling on the weekends. The map in Figure 3.6 is similar to that in Figure 3.4, but it focuses on the weekends in 2006 instead of the weekdays. As the map shows, stretches on many of the freeways in the county routinely experience congested travel conditions for at least several hours per day on the weekends.

Figure 3.6
Average Hours per Day During Which Speed Averaged Less Than 35 mph in General-Purpose Lanes, 2006 Weekends

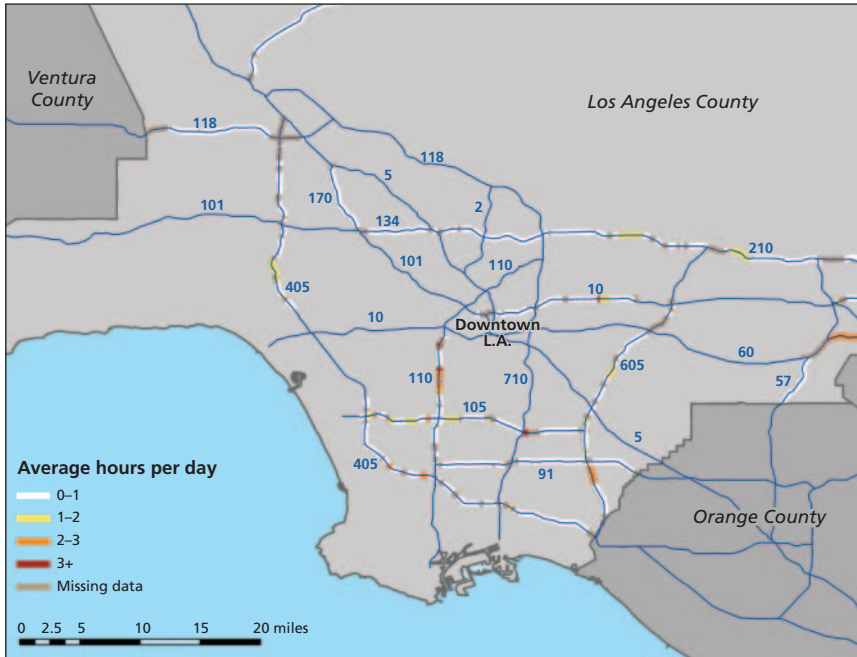


SOURCE: PeMS (undated).

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Though HOV lanes are intended to offer travel-time savings to travelers who choose to carpool, the region's network of HOV lanes is becoming increasingly crowded as well. The map in Figure 3.7 shows the average number of hours per day, for weekdays in 2006, during which the flow in HOV lanes exceeded 1,600 vehicles per hour. When HOV flow reaches this level, the lanes are considered to be *saturated*—that is, additional flow beyond 1,600 vehicles per hour will quickly lead to a degradation in travel-time performance in the lanes (Turnbull, 2002b).

Figure 3.7
Average Hours per Day During Which Average Hourly HOV-Lane Volume Exceeds 1,600 Vehicles, 2006 Weekdays



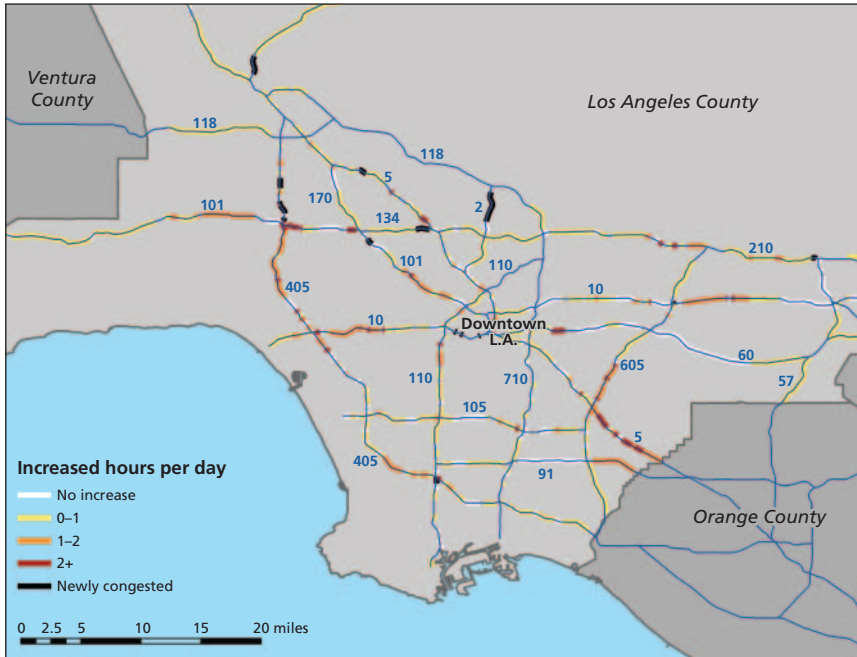
SOURCE: PeMS (undated).

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PeMS data also make it possible to examine how conditions on the region's freeway network have deteriorated in recent years. The map in Figure 3.8 displays the increase between 2001 and 2006⁵ in the number of hours per weekday with average travel speeds below 35 mph. Highway segments shown in black represent areas where congested travel conditions were minimal (averaging less than 0.1 hours per weekday) in 2001 but became more routine (exceeding one hour per weekday) by 2006. The segments shown in yellow, orange, and red, in turn, represent areas where congested travel conditions already existed in 2001 and have increased since then. In short, the map shows

⁵ The first and last years for which complete PeMS data were available during the study.

Figure 3.8
Growth in Hours per Weekday During Which Average Speed Is Less Than 35 mph, 2001 to 2006



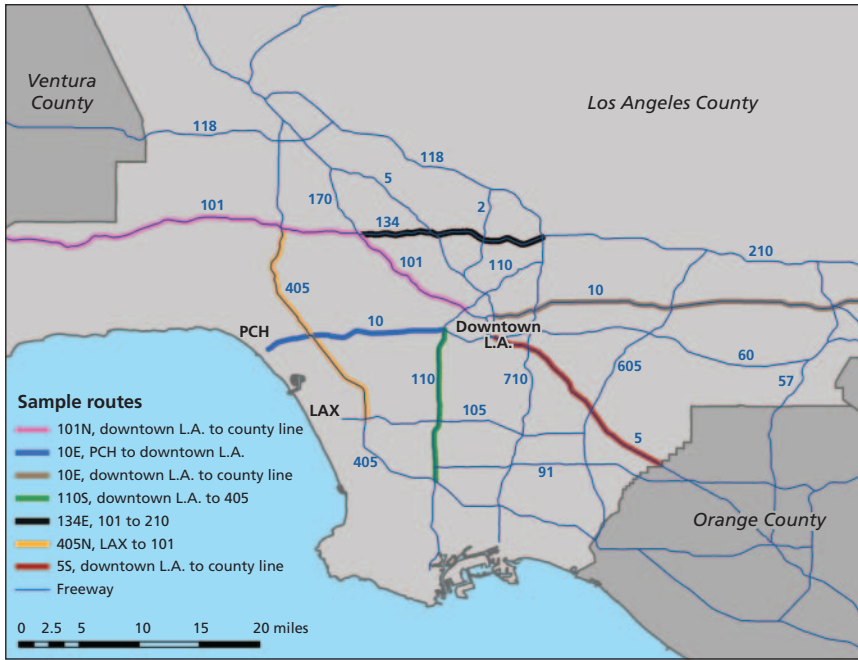
SOURCE: PeMS (undated).

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that, over just the past few years, congested travel conditions have increased considerably both in spatial extent and temporal duration.

While drivers are understandably concerned with the average level of congestion-related delays, available evidence suggests that they also place considerable value on the *reliability* of travel time—that is, the expected level of variation between how long a trip might take on one day versus another (Bates et al., 2001; Brownstone and Small, 2005). To evaluate the reliability of travel times on the freeway network in Los Angeles, we first constructed seven sample routes on which one might expect to encounter congestion during the evening rush-hour period. These are shown in the map in Figure 3.9.

Figure 3.9
Sample Routes for Freeway Travel Time–Variability Analysis



SOURCE: PeMS 2007.

NOTE: PCH = Pacific Coast Highway. LAX = Los Angeles International Airport.

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Using data from PeMS, we estimated how long it would take to drive these routes between 5:00 p.m. and 6:00 p.m. for each weekday in 2006. By examining the resulting distribution of estimated travel speeds and travel times, it was possible to characterize the variation that a traveler might expect from one day to the next. Table 3.1 provides an overview of our results. The first three grouped columns list the fifth (p5), 50th (p50), and 95th (p95) percentiles for average travel speeds (from faster to slower) over the length of each sample route between 5:00 p.m. and 6:00 p.m., while the second group of three columns displays the corresponding travel-time estimates. The final two columns indicate the increase in travel time (in minutes and in percentage terms) between p5 and p95.

Table 3.1
Speed and Travel-Time Variability for Sample Freeway Routes

Sample Route	Travel-Speed Percentiles (mph)			Travel-Time Percentiles (minutes)			Additional Delay (p95 versus p5)	
	p5	p50	p95	p5	p50	p95	Minutes	Percentage
101N: downtown to county line (36.1 miles)	60.3	46.8	34.0	35.9	46.3	63.7	27.8	77
10E: PCH to downtown (13.1 miles)	50.7	30.5	22.0	15.5	25.7	35.7	20.3	131
10E: downtown to county line (30.6 miles)	49.4	34.6	25.4	37.1	53.1	72.3	35.1	95
110S: downtown to 405 (12.5 miles)	54.7	40.5	33.2	13.7	18.5	22.6	8.9	65
134E: 101 to 210 (13.0 miles)	62.3	49.0	34.1	12.5	15.9	22.8	10.3	83
405N: LAX to 101 (17.4 miles)	51.2	34.2	26.8	20.3	30.4	38.8	18.5	91
5S: downtown to county line (16.0 miles)	41.8	29.1	22.8	23.0	33.0	42.3	19.3	84

SOURCE: PeMS (undated).

The data in Table 3.1 make it clear that travel times on the region's freeway system are, in fact, quite unreliable. At p95, travel times for many of our sampled routes are almost double that for p5, and, in one case, the increase in travel time is more than 130 percent. Even when comparing p95 with p50 (the median), the increase in the number of minutes required for a trip is considerable. As a result, any time a person is making a trip for which arriving on time is very important, it will be necessary to build in a substantial allowance of additional travel time in case conditions on the roadway happen to be more severe than expected. It is also worth noting that our estimates encompass only the portions of a trip that take place on the freeway itself. Most journeys incorporate some travel on the arterial network at the beginning and end of the trip as well, and conditions on the arterial network could further contribute to the variability in travel times.

The Arterial System Appears Especially Congested on the Westside

While the preceding set of maps focused on the region's freeway network, travel conditions on the arterial system are likewise of great interest. Unfortunately, comprehensive empirical data for conditions on the arterial network throughout Los Angeles were not available.⁶ We therefore relied on estimates of arterial-flow characteristics based on the regional transportation-forecasting model employed by SCAG in developing its long-range regional-transportation plan (SCAG, 2003).⁷ Specifically, we examined modeled flow volume and capacity data calibrated for travel conditions in 2004.⁸

⁶ Several agencies, such as LADOT, do collect real-time data on travel conditions for some portions of the arterial network, but these data are not archived beyond a few days (Bernstein, 2007). It was thus not possible to evaluate historical data across the arterial network.

⁷ SCAG provided data in electronic format.

⁸ Note that, while the SCAG-modeled data are useful in developing a snapshot of average travel conditions on the arterial network at the aggregate level, they are not necessarily accurate for each individual link in the network. Nor, for that matter, do they provide a sense of

Among travelers who live or work on the Westside of Los Angeles, a common complaint is that traffic is especially severe in this area of the county. Based solely on PeMS data for the freeway network, illustrated in the last several figures, this assertion would not appear to hold. Indeed, traffic hotspots on the freeway system are distributed throughout much of L.A. County. Data for the arterial system, in contrast, suggest another story.

The map in Figure 3.10 shows the volume-to-capacity (V/C) ratio⁹ for links in the arterial network during the afternoon peak period. Here again, heavily congested corridors appear to be spread throughout much of the county. The level of congestion on the arterial network, however, appears to be especially concentrated between downtown and the Westside. The visual interpretation of this map is broadly consistent with data from a recent report by LADOT (2005), which show that more than one-third of the 75 intersections with the highest traffic volume in the city of Los Angeles are located on the Westside. In short, the perceptions of severe traffic on the Westside, at least on the arterial network, appear valid. This suggests that any strategies aimed at reducing congestion on the arterial system could be especially helpful in this area.

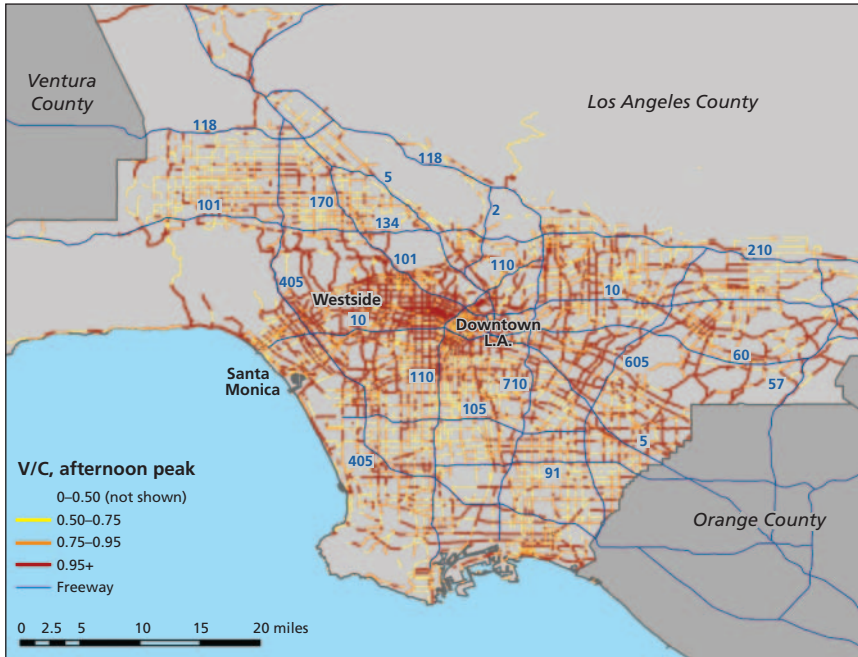
Truck Flows Are Concentrated in Certain Areas and Corridors

The SCAG data also include modeled estimates of truck flows on the arterial and freeway networks in Los Angeles. The map in Figure 3.11 displays estimates of the percentage of traffic flows resulting from truck travel on different links in the network over the course of an average

how travel conditions on the arterial network may vary from one day to the next. As such, the sophistication of analysis possible with the SCAG data is limited.

⁹ That is, an estimate of the hourly demand for travel on each link relative to the maximum number of vehicles that the link can carry. As this ratio nears a value of 1.0, a link becomes increasingly congested.

Figure 3.10
Modeled Arterial Volume-to-Capacity Estimates for the Afternoon Peak, 2004



SOURCE: 2004 regional transportation-model data provided by SCAG staff.

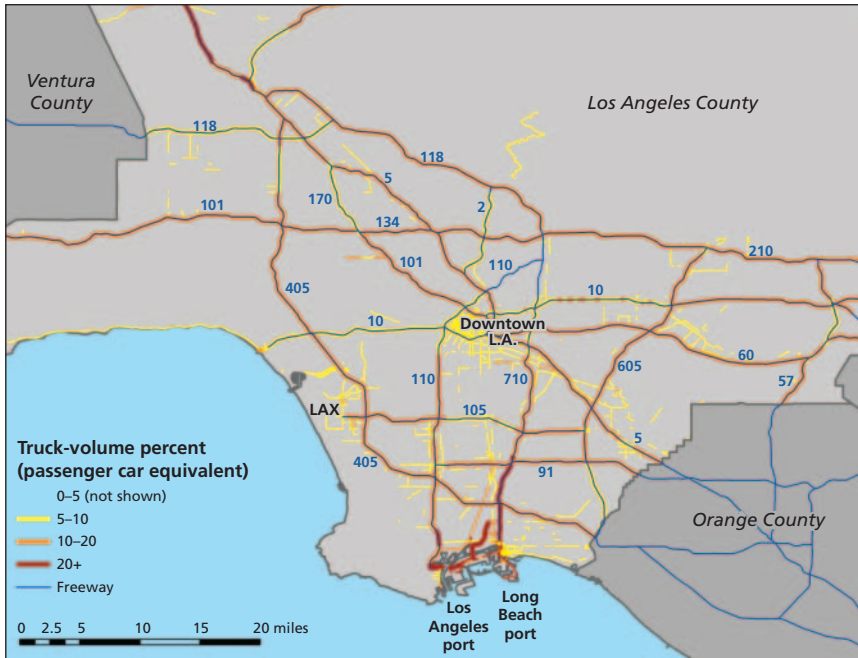
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day in 2004.¹⁰ As discussed earlier, truck traffic in the L.A. region has grown much more rapidly than passenger travel over the past several decades. This reflects the continued trend toward globalization along with the strategic importance of the twin Ports of Los Angeles and Long Beach as a key node in the global supply chain.

Even with the recent acceleration in goods movement, heavy truck traffic is not yet ubiquitous throughout the entire road network. Not surprisingly, it constitutes a larger share of traffic on freeway links

¹⁰ These estimates incorporate the concept of *passenger-car equivalence*, which accounts for the fact that the average truck takes up more space on a road than the average passenger vehicle. For example, if one truck and nine cars were on the road, the truck would be counted as more than 10 percent of the traffic.

Figure 3.11
Modeled Daily Truck Travel as Percent of Traffic Volume, 2004



SOURCE: 2004 regional transportation-model data provided by SCAG staff.

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than on arterials. It also appears to be concentrated, on the arterial system at least, in certain areas, such as the Ports of Los Angeles and Long Beach, LAX, downtown Los Angeles, and several other logistics hubs scattered throughout the county. Should the level of truck traffic continue to grow as forecasted in the coming decades, it is not apparent that the spatial distribution of truck movements will change all that much. After all, trucks will still pick up loads at the ports and drop them off in the same activity centers and distribution hubs. What is clear, however, is that trucking activities on the freeway network, around the ports and the downtown area, and at other distribution centers in the region will intensify considerably.

Summary

The goal in this chapter has been to characterize congestion in Los Angeles, including current conditions and recent trends. Our findings suggest, first and foremost, that Los Angeles is home to the most severe traffic conditions in the country. Moreover, congestion in the region has continued to intensify over the past several decades.

More detailed analysis of the freeway and arterial networks in L.A. County led to several observations. First, congested travel conditions are ubiquitous on the freeway network, and freeway travel times are extremely variable from one day to the next. Second, though areas of congestion on the arterial system are likewise spread throughout the county, arterial traffic appears to be especially heavy on the Westside. Third, truck traffic is most heavily concentrated on the freeway system and around certain key freight origins and destinations, such as the Ports of Los Angeles and Long Beach, LAX, downtown Los Angeles, and other key logistics hubs in the region.

In the previous chapter, we noted that trends in the underlying causes—growth in population, growth in the economy, and diminished investment in transportation infrastructure—suggest that congestion will continue to worsen in future years. SCAG’s most recent long-term regional transportation plan reached the same conclusion (SCAG, 2007b). Absent any improvements, SCAG projects that, by 2035, average travel speed in the region will decrease by about 4 mph, while average daily per capita delays on the road network will increase by about 10 minutes (roughly 50 percent). Even if all transportation improvements included in the long-range plan are completed, SCAG still projects that the average travel speed in the region will decrease by almost 2 mph, while average daily per capita delays on the road network will increase by about 5 minutes (roughly 25 percent). In short, even under the current master plan for transportation improvements in Southern California, congestion is expected to increase significantly during the coming decades.

Diagnosing Congestion in Los Angeles

The figures, tables, and statistics presented in the preceding chapter demonstrate that Los Angeles leads the nation in congestion, both at the aggregate level and on a per-person basis. This gives rise to the question, just what is it about Los Angeles that sets the region apart from other metropolitan areas? Why, specifically, is traffic in Los Angeles worse than in other cities? This conundrum is interesting from a purely intellectual perspective, and academics have spent years trying to untangle the intricacies of traffic in the region. More important in the context of this study, however, is that gaining insight into this question may suggest that certain strategies for reducing congestion hold promise, while others are less likely to succeed.

Theories abound as to the fundamental causes underlying the severity of congestion in Los Angeles. Some suggest that the region's long-standing love affair with the automobile, in combination with ample free parking, causes residents in Los Angeles to drive more than others. Others may posit that the region has not invested enough in new roads or world-class transit infrastructure. Still others may argue that the extreme complexity of the political environment in Los Angeles leads, inevitably, to ineffective transportation-policy decisions. While there is a grain of truth in some of these hypotheses, we find that the story is incomplete unless one also considers the high degree of density and polycentricity that characterizes urban form in Los Angeles—two factors that play an enormous role in the severity of congestion in the greater L.A. region. We also note that freight traffic from the Ports of

Long Beach and Los Angeles is an important contributor to congestion in Los Angeles, especially along certain freeway corridors.

Inadequate Explanations for the Severity of Congestion in Los Angeles

Given the prevailing levels of congestion, one might hypothesize that denizens of Los Angeles—one of the cradles of auto-oriented development—must drive more than other urban dwellers. As shown in Table 4.1, however, this is not the case. Among the 14 metropolitan areas classified as “very large” in the TTI annual mobility study (Schrank and Lomax, 2007), Los Angeles ranks just fifth in daily per capita VMT, fifth in average household automobile ownership, and ninth in single-occupant vehicle (SOV) commute-share (the percent of employees who drive to work alone).

Another plausible assumption might be that Los Angeles has provided insufficient road capacity. The data, however, do not support such a hypothesis. Figure 4.1 shows the supply of highway and arterial capacity in the urbanized areas¹ of the nation’s largest metropolitan areas, expressed in terms of lane-miles per square mile. By this metric, Los Angeles far surpasses its nearest competitor, Detroit, and its supply of arterial roads appears to be especially dense relative to other regions. If one examines the number of lane-miles on a per capita basis, again relying on TTI data, Los Angeles ranks eighth among the 14 largest U.S. metropolitan areas, falling roughly in the middle of the pack. Expressed either in per-area or per capita terms, then, Los Angeles does not appear to be lacking in road capacity in comparison with its peer regions throughout the county.

Proponents of alternative transportation might argue that the severe level of congestion in Los Angeles results not from lack of sufficient road supply but from an inadequate provision of competitive

¹ The U.S. Census Bureau classifies neighborhoods (census block groups or blocks) for which the population density exceeds 1,000 persons per square mile as *urbanized* (U.S. Census Bureau, 2002).

Table 4.1
Automobile Statistics for Large U.S. Metropolitan Areas

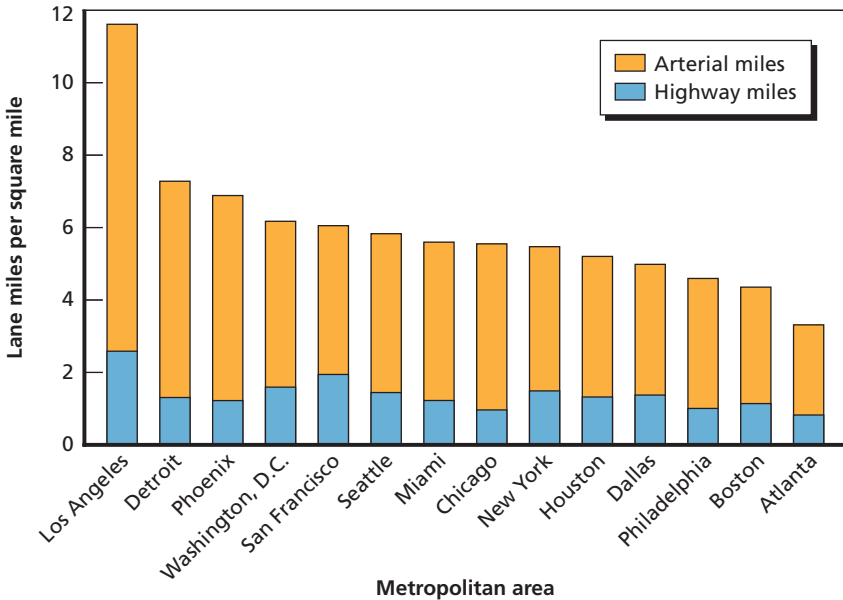
Metropolitan Region	Daily VMT Per Capita		Autos per Household		SOV Mode Share ^a	
	n	Rank	n	Rank	n	Rank
Dallas	23.2	1	1.74	4	78.8	2
Houston	22.6	2	1.68	7	77.0	3
Atlanta	22.6	3	1.80	2	77.0	3
Detroit	21.3	4	1.71	5	84.2	1
Los Angeles	21.2	5	1.71	5	72.4	9
San Francisco	19.6	6	1.76	3	68.1	13
Phoenix	19.1	7	1.67	8	74.6	6
Seattle	19.0	8	1.81	1	71.6	10
Boston	18.8	9	1.58	10	73.9	7
Washington, D.C.	18.6	10	1.66	9	70.4	12
Miami	17.2	11	1.51	12	76.6	5
Philadelphia	15.8	12	1.51	12	73.3	8
Chicago	13.0	13	1.56	11	70.5	11
New York	12.0	14	1.26	14	56.3	14

SOURCE: McGucken and Srinivasan (2003), Schrank and Lomax (2007).

^a The term *mode share* indicates the percentage of trips relying on a certain mode. As noted by Pisarski (2006), the nationwide commute mode share (according to 2000 U.S. census data) is approximately 75 percent for solo driving, just over 12 percent for carpooling, less than 5 percent for transit, less than 3 percent for walking, and less than 1 percent for biking. Though respective mode shares for all trips (as opposed to just commutes) may differ to some degree, these statistics still suggest the dominance of the automobile as the primary mode of transportation in the United States.

transit services. Table 4.2, drawing on data provided by the American Public Transit Association (APTA, 2007), provides several statistics

Figure 4.1
Lane-Mile Supply in Major Metropolitan Areas



SOURCE: Schrank and Lomax (2007).

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characterizing transit systems in the largest metropolitan areas in the country.²

According to these statistics, the transit system in Los Angeles appears robust. The largest transit operators in Los Angeles³ provide approximately 155 million revenue-miles⁴ of bus service each year (second only to New York). This ranks first among major metropoli-

² APTA provides the total transit-supply statistics in Table 4.2; the per-square-mile and per capita statistics are based on land area and population data for the urbanized areas in major metropolitan regions according to the most recent TTI urban mobility report (Schrank and Lomax, 2007).

³ The APTA report includes data for the 100 largest bus operators in the nation. This includes many, but not all, of the bus operators in Los Angeles. Thus, total bus service in the Los Angeles region will be somewhat greater than suggested by the data in the table.

⁴ The total number of miles driven by buses while in service.

Table 4.2
Provision of Transit in Large U.S. Metropolitan Areas

Metropolitan Area	Annual Bus-Revenue Miles					Rail Track-Miles				
	Total (millions of miles)	Per Square Mile		Per Capita		Total (miles)	Per Square Mile		Per Capita	
		Thousands of Miles	Rank	Miles	Rank		Miles	Rank	Miles per Million	Rank
Los Angeles	155.3	67.9	1	12.4	3	790.5	0.35	7	63.0	7
San Francisco	73.4	57.8	2	17.7	1	486	0.38	4	117.4	5
Washington, D.C.	58.1	44.4	3	13.6	2	459.8	0.35	6	107.4	6
New York	211.3	44.2	4	11.9	4	3,532.6	0.74	1	198.7	3
Miami	56.8	33.8	5	10.6	7	169.3	0.10	9	31.8	10
Chicago	87.2	31.1	6	10.7	6	1,562.2	0.56	2	191.9	4
Houston	41.6	21.8	7	11.0	5	20	0.01	12	5.3	12
Philadelphia	45.5	20.0	8	8.6	8	1,110.7	0.49	3	209.6	1
Detroit	27.7	19.2	9	6.8	11	2.9	0.00	13	0.7	13
Phoenix	22.1	19.1	10	6.8	12	0	0.00	14	0.0	14
Dallas	34.9	15.2	11	7.8	9	141.7	0.06	10	31.9	9
Boston	29.9	13.4	12	7.3	10	834.4	0.37	5	204.8	2

Table 4.2—Continued

Metropolitan Area	Annual Bus-Revenue Miles					Rail Track—Miles				
	Total (millions of miles)	Per Square Mile		Per Capita		Total (miles)	Per Square Mile		Per Capita	
		Thousands of Miles	Rank	Miles	Rank		Miles	Rank	Miles per Million	Rank
Seattle	15.0	11.9	13	5.0	14	151.9	0.12	8	50.5	8
Atlanta	21.8	7.1	14	5.2	13	103.7	0.03	11	24.9	11

SOURCE: Schrank and Lomax (2007), APTA (2007).

tan areas on the basis of service per square mile and third in terms of service per capita. For rail transit—including commuter rail, light rail, and subways—the system in Los Angeles encompasses a total of 791 track-miles. This ranks seventh among the top 14 metropolitan areas in both per-area and per capita terms. In short, Los Angeles appears to supply a significant level of bus service and a moderate level of rail service in comparison with its peers by these measures.

A final suggestion that we have encountered in talking with knowledgeable observers during the course of this project is that the jurisdictional complexity in the county may hinder more-effective regional transportation planning, thus undercutting efforts to curb congestion. Responsibility for various facets of transportation in the region is divided among numerous governing bodies and agencies, including 88 municipalities, 16 municipal transit providers, the County, Metro, and several regional and state entities, such as SCAG, the South Coast Air Quality Management District (AQMD), and Caltrans. Coordinating regional transportation policy across such a large group of actors is undoubtedly difficult.

Yet Los Angeles is not unique in facing jurisdictional complexity. According to the most recent U.S. census data, for example, the New York metropolitan area encompasses 668 jurisdictions, while the Chicago region includes 266. The L.A. metropolitan area (which extends beyond county boundaries) includes 155, ranking it fifth among the 14 largest metropolitan areas in the country. So while jurisdictional complexity may add to the challenges of effective transportation planning in Los Angeles, other regions face this same problem as well.

Urban Form in Los Angeles Is Both Dense and Polycentric

One attribute of Los Angeles that makes it stand out from its peers is high population density at the regional level. This comes as a surprise to many, as downtown Los Angeles does not seem to be as dense as, say, Manhattan, San Francisco, or downtown Chicago. Yet the suburbs outside of downtown Los Angeles are quite densely populated in relation to the suburbs surrounding other major cities in the United

States. As a result, the aggregate density of the L.A. region is the highest among the country's 14 largest metropolitan areas. This is illustrated in Table 4.3.

Of the 14 metropolitan areas listed in Table 4.3, Los Angeles ranks just eighth in terms of population density in the central-city area.⁵ For the urbanized area outside of the central city, however, Los Angeles has by far the highest density, with San Francisco the only other region that comes close. Including both the central city and outlying areas together, Los Angeles is the densest metropolitan area in the country.

It is interesting to note that the outlying areas in the L.A. region are almost as dense as the city itself—about three-quarters as dense. This pattern, though not entirely unique, is rare. Consider, in contrast, San Francisco and New York, the next two densest regions. In San Francisco, the outlying areas are only about 35 percent as dense as the central city; in New York, the outlying areas are only about 10 percent as dense as the central city. As Manville and Shoup (2005, p. 238) noted, “[T]he New York and San Francisco urbanized areas look like Hong Kong surrounded by Phoenix, while the Los Angeles urbanized area looks like Los Angeles surrounded by . . . well, Los Angeles.”

Along with a high degree of density at the regional scale, Los Angeles is also characterized by a pattern of land use that can be described as polycentric (Giuliano and Small, 1991). That is, rather than a single dominant downtown area like one would find in New York or Chicago, Los Angeles has many subcenters with high population or job densities—such areas as downtown Los Angeles, Century City, Westwood, Santa Monica, Long Beach, Glendale, and Pasadena. Downs (2004) noted, for example, that L.A. County contains 25 suburbs with population densities greater than 10,000 persons per square mile.

A recent study by Giuliano, Redfearn, et al. (2007) found similar dispersal of job centers, identifying 15 employment clusters in the greater L.A. region with 20,000 or more jobs and a density of at least 20 jobs per acre (referred to as the *20/20 criterion*), 12 of which lie in L.A. County (the other three are in Orange County). The study

⁵ That is, the area in the city of Los Angeles boundaries designated by the U.S. Census Bureau as *urbanized*.

Table 4.3
Population Density in 14 Largest U.S. Metropolitan Areas

Metro Area	Urbanized Area				Urbanized Area In Central City				Urbanized Area Outside Central City			
	Pop.	Area (sq. mi.)	Pop. per Sq. Mi.	Rank	Pop.	Area (Sq. Mi.)	Pop. per Sq. Mi.	Rank	Pop.	Area (sq. mi.)	Pop. per Sq. Mi.	Rank
Los Angeles	11,789,487	1,668	7,068	1	3,694,820	420	8,797	8	8,094,667	1,248	6,486	1
San Francisco	2,995,769	428	7,004	2	776,733	47	16,632	2	1,219,036	381	5,824	2
New York	17,799,861	3,353	5,309	3	8,008,278	299	26,784	1	9,791,583	3,054	3,207	4
Miami	4,919,036	1,116	4,408	4	362,470	35	10,356	6	4,556,566	1,081	4,215	3
Chicago	8,307,904	2,123	3,913	5	2,896,016	227	12,758	3	5,411,888	1,896	2,854	7
Phoenix	2,907,049	799	3,638	6	1,304,408	298	4,377	11	1,602,641	501	3,199	5
Washington, D.C.	3,933,920	1,157	3,400	7	572,059	62	9,227	7	3,361,861	1,095	3,070	6
Detroit	3,903,377	1,261	3,095	8	951,270	139	6,844	9	1,952,107	1,122	2,631	9
Houston	3,822,509	1,295	2,952	9	1,950,698	499	3,909	13	1,871,811	796	2,352	11
Dallas	4,145,659	1,407	2,946	10	1,185,866	288	4,118	12	2,959,793	1,119	2,645	8
Philadelphia	5,149,079	1,800	2,861	11	1,517,550	135	11,241	5	3,631,529	1,665	2,181	12
Seattle	2,712,205	954	2,843	12	563,374	84	6,707	10	2,148,831	870	2,470	10
Boston	4,032,484	1,736	2,323	13	589,141	47	12,535	4	3,443,343	1,689	2,039	13

Table 4.3—Continued

Metro Area	Urbanized Area				Urbanized Area In Central City				Urbanized Area Outside Central City			
	Pop.	Area (sq. mi.)	Pop. per Sq. Mi.	Rank	Pop.	Area (Sq. Mi.)	Pop. per Sq. Mi.	Rank	Pop.	Area (sq. mi.)	Pop. per Sq. Mi.	Rank
Atlanta	3,499,840	1,963	1,783	14	416,425	132	3,155	14	3,083,415	1,831	1,684	14

SOURCE: Manville and Shoup (2005); based on 2000 U.S. Census Bureau data.

also noted that jobs appear to be decentralizing over time. Using the same 20/20 criterion, the authors determined that the total number of employment clusters in the region has increased from 10 to 15 between 1980 and 2000, while the number of jobs in downtown Los Angeles—the largest of the clusters—has decreased by about 20 percent between 1980 and 2000. Los Angeles thus appears to be growing more polycentric with time.

Greater Population Density Leads to Greater Traffic Congestion

The high aggregate level of density in Los Angeles spells trouble for congestion in the region. As a general rule, people living in dense areas drive less on a per capita basis. In part, this is because, with higher densities, the average distance between trip origins and destinations tends to decrease such that journeys by car need not be as long.⁶ In addition, shorter trip distances make it feasible to perform a larger share of journeys by other modes of travel, such as transit, walking, or biking (Litman, 2008).

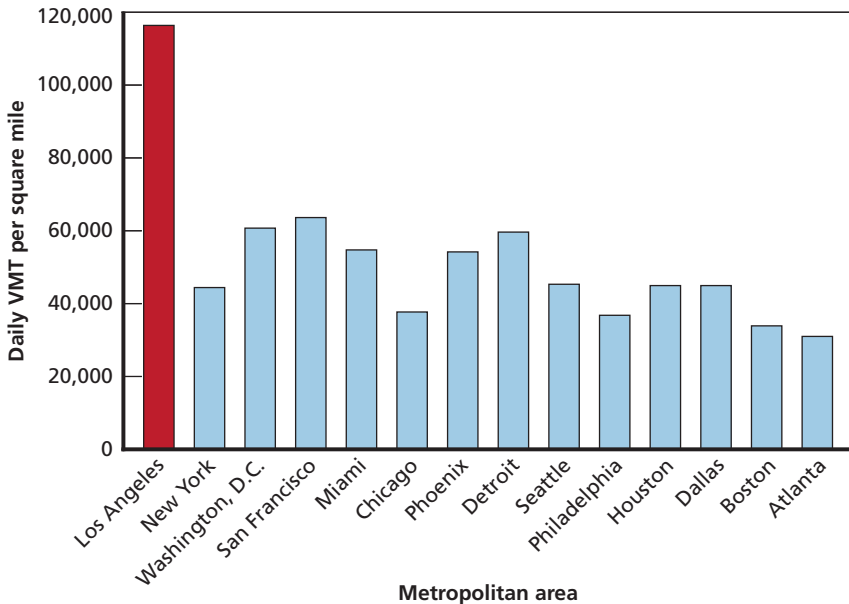
That said, the relationship between density and per capita VMT is relatively inelastic, to borrow a term from economists. That is, though per capita driving falls with increased density, it does not fall as quickly as density rises. For instance, Holtzclaw (1994) estimated that average household VMT falls by about 25 percent when density doubles, controlling for other relevant factors, such as household income. Ewing and Cervero (2001) estimated the decrease in per capita VMT relative to increases in density at about 5 percent, Litman (2008) estimated that it falls by about 20 to 30 percent, and Manville and Shoup (2005) put it at 58 percent. Regardless of the specific estimate, however, the key point is that per capita automotive travel does not fall nearly as fast as density rises. As a result, though per capita VMT declines with greater density, total VMT in a given area will increase; in other words,

⁶ However, shorter travel distances may also encourage residents to make a larger number of total trips (Downs, 2004).

there will be a greater spatial concentration of automotive travel on a per-area basis. This relationship is exhibited in Figure 4.2, which shows the spatial density of automotive travel (expressed as daily VMT per square mile) in the urbanized areas of the 14 largest metropolitan areas in the country.

Note that the metropolitan regions shown in Figure 4.2 have been listed in decreasing order of density.⁷ One can see that, as a

Figure 4.2
Spatial Density of Travel in Major Metropolitan Areas



SOURCE: Schrank and Lomax (2007).

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⁷ The population-density rankings in Figure 4.2 are slightly different from those shown earlier in Table 4.3. The data in Table 4.3, provided by Manville and Shoup (2005), are based on the 2000 U.S. census. The population-density rankings in Figure 4.2, in contrast, are based on the most recent TTI urban-mobility study (Schrank and Lomax, 2007), which uses more up-to-date census data from the American Community Survey. The resulting density calculations, as well as the rank ordering of different metropolitan regions, are therefore slightly different, though Los Angeles still ranks as the densest region.

general rule, the spatial density of automotive travel tends to decline with the level of population density (though there appear to be a few exceptions to the trend, such as New York and Chicago). Los Angeles, with the highest population density, has by far the highest density of automotive travel.

Cities can offset the increased density of travel to some extent by building more roads. Yet as density increases in urban areas, the road network cannot be expanded indefinitely. As open space becomes scarce and land values rise, the cost of building new or expanding existing roads becomes prohibitively expensive (Manville and Shoup, 2005). This makes it difficult to build enough roads to keep up with the increasing spatial density of automotive-travel demand. Consider, for example, that Los Angeles, as illustrated earlier in Figure 4.1, has already developed an extremely dense road network relative to other metropolitan regions. Yet if we compare the level of travel with the available road supply (again using data from Schrank and Lomax, 2007), Los Angeles still ranks second among the largest metropolitan regions, with close to 10,000 VMT per lane-mile. (In San Francisco, the top-ranked region, the number is roughly 10,500 VMT per lane-mile.) In other words, even with a road network that is more than 50-percent denser than its nearest competitor among major metropolitan areas, Los Angeles still has close to the highest level of automotive travel relative to total lane capacity. Moreover, it is difficult to conceive how the region might be able to expand the existing road network to any significant degree, at least in the densest and most congested areas of Los Angeles.

To recap, per capita VMT tends to decline with greater population density, while available lane capacity usually increases. The spatial density of aggregate travel demand, however, also increases. If expansion of the road network is unable to keep pace with the greater density of travel demand, the inevitable result is increased congestion. Available data suggest that this is one of the key challenges confronting Los Angeles.

Polycentricity May Reinforce Auto Dependency, Compounding Congestion

The relationship between polycentricity and congestion is complex. On one hand, origins and destinations will be distributed more evenly throughout a polycentric region. As a result, trips will be spread more broadly among different segments of the road network, and this may help ease congestion. On the other hand, polycentric land-use patterns can make transit more challenging to provide and less attractive to use. This may lead to increased reliance on the automobile, contributing to greater congestion.

One of the key challenges is that effective transit service in a polycentric region will require a more complex network. Major transit corridors in a monocentric region are often structured as a series of radial routes running from residential suburbs to the core downtown area. In a polycentric region, in contrast, suburbs must be connected with multiple job centers, and the job centers must be connected with one another as well. This increases the number of links in the network, and, in turn, the cost of providing the service.

By spreading jobs and other destinations over more locations, polycentricity also reduces the density of activity at any single location. This, in turn, reduces the potential patronage of transit lines serving each activity center,⁸ making it more difficult to justify costly investments in high-speed transit service with dedicated right-of-way, such as subways, light rail, commuter rail, or bus-only lanes. Absent higher-speed options, travelers are less likely to choose transit when they have the option of driving instead.

Finally, in a polycentric region, the destinations for different activities are, by definition, more likely to be spread across multiple locations. This reduces the ability to combine multiple errands in a single trip. In a monocentric city, an individual might be able to take transit to work, then walk to perform several errands during the day, then return home again directly after work. In a polycentric region, in

⁸ Downs (2004) noted, for instance, that the density of activity centers has a stronger influence on transit patronage than the density of residential development.

contrast, an individual is more likely to need to travel to separate locations to go to work, visit the dentist, and shop for groceries, for example. Because public transit is typically slower than traveling by car, the need to travel to different destinations to serve multiple trip purposes in a polycentric region further reduces the attractiveness of such transit options in comparison to the automobile.

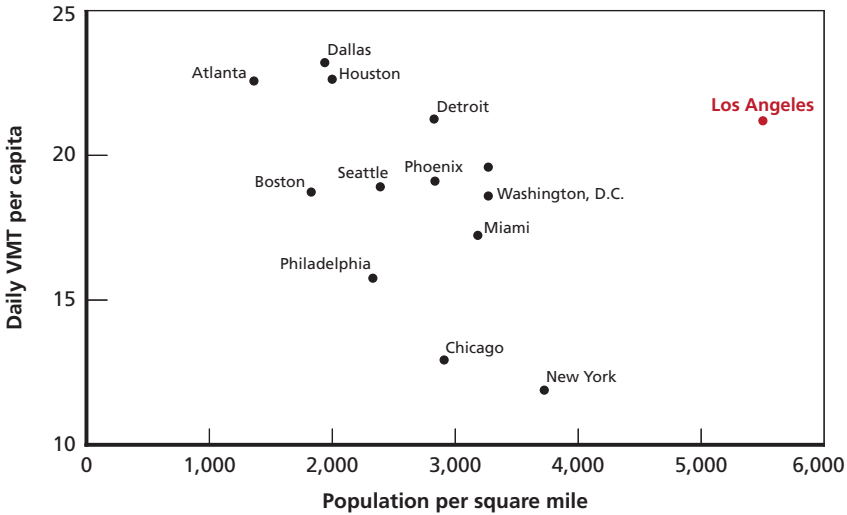
Interacting Land-Use and Transportation Patterns Result in Severe Traffic Congestion in Los Angeles

Earlier in this chapter, we noted that Los Angeles, according to a variety of transportation statistics, does not appear to stand out from its peers in a way that would explain the region's high level of congestion. When the factor of regional population density is taken into account, however, the distinctions between Los Angeles and other large cities become much more apparent. Figure 4.3, for example, presents a graph comparing regional density with daily per capita VMT for the country's largest 14 metropolitan regions.⁹

For most of the cities shown in Figure 4.3, there is a fairly consistent relationship in which per capita VMT declines with regional density. Los Angeles, however, stands as an exception. The only other large metropolitan regions in the country with higher per capita VMT, including Atlanta, Dallas, Houston, and Detroit, are all much less dense than Los Angeles. For regions in which the level of density approaches that of Los Angeles, such as San Francisco, Washington, D.C., and New York, in turn, per capita VMT is much lower. We thus see a confluence of three density-related factors that, in combination, help to explain the severity of congestion in Los Angeles: (1) that congestion, as noted, is likely to rise with increased population density; (2) that Los Angeles is much denser at the regional level than its peers are; and (3) that Los Angeles exhibits a surprisingly high level of per capita VMT relative to its density.

⁹ Here again, we use the more recent density calculations based on data from Schrank and Lomax (2007).

Figure 4.3
Population Density and Daily Per Capita Vehicle-Miles Traveled in Major Metropolitan Areas



SOURCE: Schrank and Lomax (2007).

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When attempting to diagnose the problem of congestion in Los Angeles, it is useful to consider why per capita VMT relative to density is so high in comparison to other large metropolitan areas in the United States. We can suggest two possible reasons, although there are likely other explanations as well. One possible explanation is that the network of fast, convenient transit services in the region is not as advanced as one might expect in a region as dense as Los Angeles, in part due to the challenges posed by the region's polycentric structure. A second reason is that the cost of traveling by car in Los Angeles, again relative to density, is overly subsidized. We explore each of these arguments in turn.

In considering transit as an alternative to driving, service with dedicated right-of-way offers the most compelling advantages, including higher operating speeds and greater travel-time reliability. This is

the case with heavy rail (subways), commuter rail, and light rail.¹⁰ Bus transit can also be fast and effective. For this to be the case, however, it is typically necessary to provide some form of dedicated or restricted right-of-way for bus service, such as bus-only lanes or shared bus/HOV lanes. Absent reserved right-of-way, buses will become mired in traffic congestion just like automobiles do, precluding any potential travel-time advantages that might otherwise be achieved.¹¹

Our examination of higher-speed transit thus focuses on options with dedicated right-of-way—including various forms of rail transit as well as exclusive or restricted¹² bus lanes. Figure 4.4 compares the density of higher-speed transit options (represented as rail track–miles plus busway miles per square mile in the urbanized area) with population density in each of the 14 largest metropolitan areas in the country. In compiling the information about high-speed transit options, we began with data on the number of rail track–miles in different regions as reported by APTA (2007). Next, we added the mileage for all dedicated or restricted bus lanes that we could identify in major metropolitan areas. In the greater L.A. region, we included the Orange Line, the Harbor Transitway, the El Monte Busway, and bus service on

¹⁰ The speed advantage is most pronounced for fully grade-separated transit lines, including subways (e.g., Metro Red and Purple lines in Los Angeles) and many commuter-rail lines. A greater proportion of light-rail transit lines (such as the Metro Gold, Green, and Blue lines in Los Angeles) share at-grade crossings with arterial roads and thus do not enjoy as much of a speed advantage.

¹¹ The Metro Rapid bus lines include a range of BRT features, such as signal prioritization, infrequent stops, and headway-based scheduling to make bus service more competitive (see the discussion of BRT features in Appendix B25 for more details). While these features have improved bus-travel speeds and, in turn, led to increased patronage, the Rapid buses must still share lanes with general traffic and thus are subject to congestion delays. As a result, the average daytime travel speed for Rapid buses traveling on the Wilshire corridor is just over 11 mph (Jeff, 2007a).

¹² In certain cases, we include shared bus and HOV lanes, provided that the HOV limit is set to preserve free-flowing traffic conditions. For example, the El Monte Busway allows both buses and carpools with three or more individuals. At one point, the HOV limit was reduced to two or more persons, but this quickly led to congested travel conditions in the lanes. The HOV limit was thus raised back to three or more travelers. We also include bus service in HOT lanes where prices are set to ensure free-flowing travel conditions. (HOT lanes are discussed further in the next chapter and in Appendix B18.)

Figure 4.4
Population Density and High-Speed-Transit Density in Major Metropolitan Areas



SOURCES: Schrank and Lomax (2007); APTA (2007).

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the 91 Express Lanes. High-speed bus options in other major cities include the Silver line in Boston, bus service in the Katy Freeway HOT lanes in Houston, the Miami-Dade busway, the Metro bus and light-rail tunnel in Seattle, and the Shirley Highway bus/HOV lanes in the Washington, D.C., region.

With higher density, as discussed earlier, there should be greater opportunities to provide fast and effective transit services. The data presented in Figure 4.4 suggest that denser metropolitan regions do, in fact, tend to offer more transit options with dedicated right-of-way than less dense regions do, though this trend is far from uniform. A strong relationship between density and the provision of higher-speed transit is clear among some of the older, monocentric regions, such as Boston, Philadelphia, Chicago, and New York. Among other cities, there is greater variation. Some of the more autocentric cities—Houston, Detroit, and Phoenix, in particular—offer very little in the way of transit options with dedicated right-of-way. Others—such as Washing-

ton, D.C., and San Francisco—offer more high-speed transit options, though not as many as Chicago or New York.

Los Angeles, in absolute terms, appears to provide a moderate level of transit options with dedicated right-of-way—less than New York, Chicago, and Philadelphia but on par with Boston, San Francisco, and Washington, D.C. In comparison with densities of other large metropolitan regions in the country with well-developed transit systems, however, Los Angeles lags in the provision of higher-speed transit, and this may be one reason that residents in Los Angeles drive more than one would expect, given the region's density.

This observation is not intended as an argument that Los Angeles should invest massively in major rail-transit expansions in the near future. Indeed, many of the existing rail-transit lines in Los Angeles have relatively low ridership levels,¹³ and the provision of fast and effective rail-based transit in the region is complicated by polycentric land-use patterns, as discussed earlier. For example, though Los Angeles is quite dense at the regional level, its central-city area, as shown earlier in Table 4.3, is not as dense as many others. In fact, of the six metropolitan regions for which the density of transit service with dedicated right-of-way meets or exceeds that of Los Angeles (Boston, Chicago, New York, Philadelphia, San Francisco, and Washington, D.C.) all have denser central cities than Los Angeles has. It may well be the case that, while Los Angeles is sufficiently dense at the regional level to support cost-effective bus service,¹⁴ it has fewer areas and corridors sufficiently dense to justify more costly investments in high-speed, high-capacity rail service (Eidlin, 2005).

Given that Los Angeles is both dense and heavily congested, however, providing additional options for higher-speed transit service would be helpful. In certain corridors, such as Wilshire Boulevard, the demand for transit may well be high enough to justify investment in

¹³ Of Metro's Red, Purple, Green, Blue, and Gold lines, only the Red line has daily boardings in excess of 100,000 (Jeff, 2007a).

¹⁴ Downs (2004), citing a study by Pushkarev and Zupan (1977), suggested that residential densities on the order of 4,200 to 5,600 persons per square mile are necessary to support cost-effective bus service.

rail. In other cases, however, it may be faster and more cost-effective to enhance the speed and reliability of transit by providing bus-only lanes on the arterial network. We return to this idea in the next two chapters.

Another possible explanation for the high level of per capita driving in Los Angeles relative to the region's density is that the cost of driving in Los Angeles is more subsidized than elsewhere. Some of the key cost components of driving include auto ownership or leasing, insurance, fuel, tolls, and parking. Of these, the first three are not likely to be substantially less in Los Angeles than in other regions.¹⁵ Nor are residents of Los Angeles yet subject to tolls in the county. This leads to the consideration of parking as a possible explanation. As Shoup (1997) demonstrated, the true cost of parking may represent half or more of the cost of the average commute in Los Angeles, so the direct or indirect subsidization of parking expenses can exert significant influence on the decision of whether to drive.

According to basic economic principles, as the supply of parking increases, the price should decline, all else equal. Where parking is abundant, then, the cost should be cheap (or even free). In denser regions, however, one would not expect to find an overabundance of parking. Because land values rise with density, the provision of parking in surface lots is not an economically productive use of land. Instead, parking in dense environments is typically provided in multistory structures, either above or below ground. This raises the cost of parking capacity considerably. Whereas the per-space construction cost of surface parking is quite low—perhaps a few hundred dollars, or at most a few thousand, for some asphalt and paint—building structured parking is an expensive undertaking. Shoup (2005), for instance, cited examples of parking structures in the United States costing in the range of \$20,000 to \$60,000 per space to build. At the same time,

¹⁵ In fact, the cost of gasoline in Los Angeles and the rest of California is typically much higher—by as much as \$0.30 or \$0.40 per gallon—than elsewhere in the United States, in part due to the state's stringent formulation requirements (Borenstein, Bushnell, and Lewis, 2004).

higher land values correspond to higher potential rents for floor space dedicated to residential or commercial purposes instead of parking.

Because parking costs more to construct, and because it must compete with other profitable allocations of constructed floor space, the market rate for available parking spaces will tend to rise in higher-density regions. This, in turn, will drive down demand for parking. That is, with higher parking charges, more travelers will be willing to walk, bike, ride transit, or carpool to avoid or reduce the amount that they must pay to park. Developers, in response, will tend to reduce the amount of parking spaces that they provide. Developers will still offer some parking spaces—we live, after all, in an automobile-oriented society, and there are many willing to pay a high price for the convenience of being able to park at their chosen destination—but the economics dictate that the number of parking spaces relative to square footage of building space should decline with greater density.

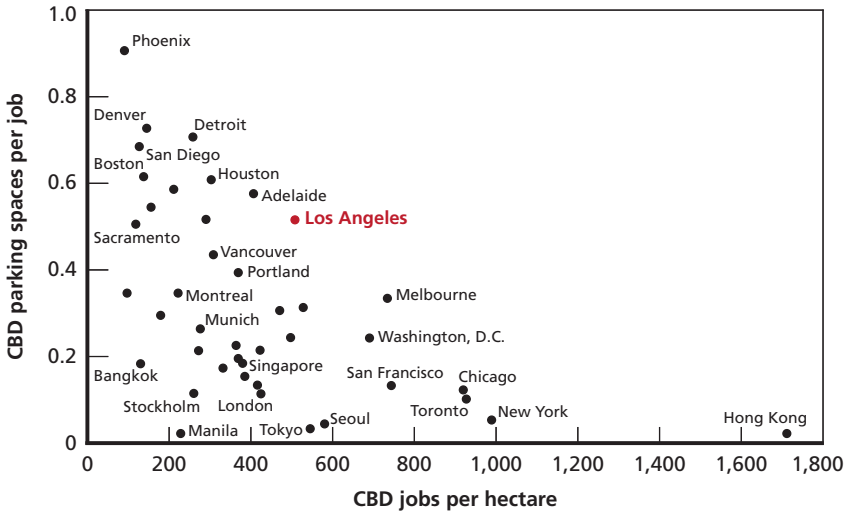
Given the high aggregate density of Los Angeles, according to this reasoning, one might expect to find a relatively constrained supply of parking with high parking charges. In fact, the opposite is the case, with many areas in Los Angeles characterized by an abundance of cheap or free parking. This is the result, to a large degree, of regulatory intervention in the form of minimum parking requirements embedded in the zoning codes of most municipalities in the region (Shoup, 2005). In essence, minimum parking requirements prescribe a floor on the number of parking spaces to be provided with a new development, based on some measure of building capacity (such as the number of square feet in an office building or the number of tables in a restaurant) given assumptions about the number of additional vehicle trips that will be generated by the activities conducted in the building.

The original intent of minimum parking requirements was to prevent additional traffic visiting the building from overcrowding the available supply of curbside parking in the area (Shoup, 2005). The practical effect, however, has been to raise the aggregate supply of parking in Los Angeles—often far beyond the amount that developers would choose to provide under free-market conditions. Raising the supply of parking in turn reduces the average price demanded for each space, thus reducing the cost of driving in the region. This indirect sub-

sidization of parking may thus represent another important reason that residents of Los Angeles drive more per capita than one would expect based on the density of the region. As stated in a recent article in *The Economist* (“Redesigning Cities,” 2008, p. 39), “A big reason Angelenos drive everywhere is that they can park everywhere, generally free.”

To illustrate the abundance of parking relative to density in Los Angeles, Figure 4.5—based on data collected by Kenworthy and Laube (1999) as reported by Manville and Shoup (2005)—compares the density of jobs with the supply of parking spaces per job in the central business district (CBD) for many of the largest cities in the United States and abroad. As a general rule, the supply of parking relative to demand (spaces per job) declines with density (jobs per hectare)¹⁶,

Figure 4.5
Density of Jobs Versus Parking Spaces per Job in the Central Business District for Major World Cities



SOURCE: Kenworthy and Laube (1999) as reported by Manville and Shoup (2005). Cities plotted but not labeled include Calgary, Edmonton, Ottawa, Winnipeg, Amsterdam, Brussels, Copenhagen, Frankfurt, Hamburg, Paris, Vienna, Zurich, Brisbane, Sydney, and Kuala Lumpur.

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¹⁶ One hectare equals 10,000 square meters, or 2.471 acres.

though considerable variation remains from one city to the next. Cities that lie closer to the origin of the graph (the lower-left corner) provide fewer parking spaces per job relative to density, while cities that lie farther from the origin provide a greater abundance of parking. Los Angeles clearly falls in this latter group.

In fact, the abundance of parking in Los Angeles may be even more extreme than Figure 4.5 would suggest. Based on the size of the L.A. CBD, the number of jobs in the CBD, the number of parking spaces per job, and the average size of a parking space, Manville and Shoup (2005) estimated that the supply of parking in the L.A. CBD, if it were spread evenly over the surface at ground level, would consume about 81 percent of the land in the CBD. This figure is higher than for any other city considered in their survey.¹⁷ Some cities have more parking spaces per job but fewer jobs per hectare, while others have more jobs per hectare but fewer spaces per job. When the two factors are considered in combination, Los Angeles proves to be the most extreme case.

To help stem the growth of congestion in Los Angeles, it would be beneficial to reconsider the current practice of mandating minimum parking requirements in municipalities throughout the region. There are several alternatives. Perhaps the easiest would be to simply eliminate parking requirements—that is, to let the market determine the appropriate supply of parking. Given the value of land in the denser regions of Los Angeles and the high cost of constructing parking facilities, developers would, in many cases, choose to build fewer rather than more parking spaces. An even more aggressive option would be to enforce maximum rather than minimum parking limits on new development. Recognizing that more parking means cheaper parking, which, in turn, stimulates more automotive travel, San Francisco and several other cities have taken this tack (Shoup, 2005).

Revising policies related to providing off-street parking in Los Angeles would do little to change the level of travel in the region in the short term. Land-use patterns, after all, evolve slowly over a period

¹⁷ For Melbourne and Adelaide, the next-closest cities, the estimates are 76 and 73 percent. For Houston, the closest city in the United States, the estimate is 57 percent.

of decades with successive waves of redevelopment. In the longer term, however, reducing the supply of parking relative to density in Los Angeles should have a powerful effect in stemming continued growth in automotive travel and, in turn, congestion in the region. Also, several strategies related to the pricing of existing parking capacity (as opposed to the supply of new capacity) could be implemented in a short time frame. We consider these in the next two chapters.

Significant Freight Traffic Also Contributes to the Severity of Congestion in Los Angeles

In discussing the causes of traffic congestion in Los Angeles, it is also important to acknowledge the significant and growing role of freight traffic in the region. As mentioned earlier in Chapter Two, the twin Ports of Los Angeles and Long Beach collectively handle about 43 percent of the container shipments entering the United States, and the volume is expected to increase considerably in the coming decades (SCAG, 2005). Trucks transport many of the containers moving through these ports to inland freight hubs or other regional destinations. While truck traffic is not distributed uniformly throughout the region's road network (refer to Figure 3.11 in Chapter Three), it does constitute a significant share of traffic in certain areas and along certain corridors, such as parts of the 5, 60, and 710 freeways.

This book does not address congestion-reduction strategies that focus specifically on goods movement, though certain strategies (such as various forms of pricing) will likely have an effect on both trucks and passenger vehicles. Given the anticipation for continued growth in truck travel in Southern California, however, we believe that it would be useful to conduct a separate study that focuses specifically on strategies relevant to freight traffic.

Summary

Our goal in this chapter was to examine what it is about Los Angeles, in comparison to other large metropolitan regions, that gives rise to such severe congestion. When evaluating a range of relevant transportation statistics on either a per capita or per-area basis, Los Angeles does not appear to stand out that much from its peers in ways that would explain the severity of congestion in the region. Per capita VMT and auto-ownership levels are lower in Los Angeles than in several other comparable regions, and the density of the road network in Los Angeles is much greater than in any other large metropolitan region. At the same time, Los Angeles appears to provide a very high level of bus service and a moderate amount of rail transit.

Los Angeles does stand out in other important ways, though. To begin with, the regional population density of Los Angeles is greater than that of any other large metropolitan area in the country. Though per capita VMT will typically decline with increased density, the overall intensity of traffic will increase, thus creating more congestion. In addition, Los Angeles is characterized by a polycentric pattern of land use; rather than a single dominant downtown area as one might find in New York or Chicago, for instance, Los Angeles has many dense commercial and residential clusters scattered throughout the region. Polycentric land-use patterns make it more difficult to provide fast and effective transit services, all while fostering travel patterns that are less conducive to transit.

When one reexamines transportation statistics in Los Angeles in light of the region's high density and polycentricity, the sources of severe congestion become more apparent. For example, per capita VMT in Los Angeles, though not the highest among large metropolitan regions in the United States, is surprisingly high relative to population density at the regional scale. We considered two possible factors that may contribute to this outcome, though there may be additional explanations as well. First, though Los Angeles provides a moderate level of high-speed transit options with dedicated right-of-way in comparison with other large metropolitan areas in the country, the region's high level of population density suggests that there should be opportunities to offer

even more. Undoubtedly, the polycentricity of Los Angeles has made it more difficult to provide an extensive network of high-speed transit with dedicated right-of-way, and there may be relatively few travel corridors with sufficient density to justify costly investments in rail service. Yet much could be done to improve the speed and reliability of bus service at relatively low cost, such as the provision of bus-only lanes on the existing road network. Second, the supply of parking in the region—as a result of the long-standing zoning policy of minimum parking requirements—is much higher than one would expect in a region with the density of Los Angeles. This reduces the average price for parking, which, in turn, encourages more travelers to drive.

It is also important to acknowledge the significant and growing role of freight traffic in the greater L.A. area, though this tends to be concentrated in certain areas and corridors. This book does not specifically address strategies related to goods movement, but there is clearly a role for additional research on this topic.

Because Los Angeles already has a very dense road network, the prospects for reducing congestion through significant roadway expansions are limited. Providing more-compelling transit alternatives with exclusive right-of-way and reducing regulation-driven distortions in the supply of parking, on the other hand, would appear to be important long-term strategies for reducing the growth in automotive travel in Los Angeles. Yet the primary focus of this book is short-term strategies, not long-term options. Fortunately, as discussed in the next chapter, a range of available short-term measures can support similar aims.

Short-Term Congestion-Reduction Options

In this chapter, we introduce short-term congestion-reduction strategies that could be implemented in Los Angeles and discuss their strengths and weaknesses. We first describe the process through which we identified strategies and then discuss several criteria that were used to select a smaller set of options for further analysis. The strategies that meet our selection criteria—28 in all—can be organized into three broad categories:

1. strategies to increase the capacity of existing roads
2. strategies to manage or reduce peak-hour automotive travel
3. strategies to improve alternative modes of travel.

We briefly consider the potential advantages and limitations of these categories in broad terms and then enumerate the specific options included in each. We also examine where some of the more aggressive or innovative strategies are being applied in other major cities in the United States and abroad. Finally, we present a synthesis of our efforts to assess each of the short-term strategy options according to a range of criteria, such as cost/revenue implications, short- and longer-term effectiveness in reducing traffic congestion, effects on other social goals, likely political or institutional obstacles, and current level of implementation in Los Angeles.¹ This analysis informs the development of specific recommendations presented in Chapter Six.

¹ Details of the individual strategy assessments are presented in Appendixes A through B28.

Identifying Short-Term Congestion-Reduction Options

Congestion represents a long-standing urban challenge, and there is a rich academic literature discussing approaches to reducing congestion. As a starting point in our effort to identify promising strategies for Los Angeles, we reviewed books, studies, and articles that outline and discuss the many options that have been implemented or proposed (e.g., Association for Commuter Transportation, 2004; FHWA, Cambridge, and TTI, 2005; Downs, 2004; Giuliano and Hanson, 2004; VTPI, 2008b). We also reviewed previous congestion-reduction proposals and programs for Los Angeles. These included recent efforts (such as the proposed one-way alignments for Pico and Olympic Boulevards [Rifkin, 2007], LADOT's Operation Bottleneck Relief [Fisher, 2006], and former L.A. mayor James Hahn's task force on congestion, mobility, and safety [L.A. Office of the Mayor, 2004]), as well as programs from earlier decades (such as AQMD's Regulation XV for employer-based trip-reduction programs [Giuliano, Hwang, and Wachs, 1993] and the coordinated strategies employed as part of the 1984 Olympics [Giuliano, 1988]). Finally, we investigated strategies currently being planned or employed in other major U.S. and world cities known for their innovative or aggressive efforts to mitigate congestion and enhance mobility.

Based on this initial research, we identified a broad range of possibilities. Some involve enhancing the road network, either by building new facilities or by increasing the capacity or efficiency of existing infrastructure. Others focus on reducing the demand for peak-hour automotive travel through voluntary approaches, regulations, or restrictions; increasing the cost of driving and parking; or altering land-use patterns. Still others are intended to enhance alternative modes, such as public transit, biking, and walking.

To pare the initial list to a final set of strategies for further review, we employed several selection criteria:

- *Short-term implementation and effects:* The intent of this study was to identify congestion-reduction strategies that could be imple-

mented and produce noticeable effects in a short time frame, which we have defined as a period of roughly five years or less.

- *Local public-policy scope:* We also focused on strategies that could be directly implemented or influenced through the actions and policy decisions of local governments.
- *Suitable in dense urban areas:* We concentrated on strategies that would be appropriate in dense urban settings, as such areas often experience the most severe congestion. Some of the strategies included would be applicable in both urban and suburban contexts, but we did not include strategies aimed primarily at suburban areas.
- *Applicable to both passenger and freight traffic:* While we included general strategies that might apply to passenger as well as freight traffic, we did not address strategies with a primary focus on traffic issues stemming from goods movement.

One of the reasons that we chose to apply these selection criteria was to define both a logical and reasonable scope for the project given the available budget. As a result, however, we were unable to evaluate a number of potentially promising options that Los Angeles might want to consider. For instance, major capacity expansions—such as new freeway lanes or subway lines—were judged as falling outside the short-term scope. And while land-use reforms, such as mixed-use zoning or reduced off-street parking requirements, might be implemented within five years, their effects would unfold much more slowly as land-use patterns evolve with successive waves of development. Advanced forms of road pricing, such as networkwide, distanced-based tolls, which would require the installation of specialized equipment in all vehicles traveling in the region, were also omitted based on the criterion of the short-term time frame.²

² For further discussion on the various forms of congestion tolling and their technical requirements, see Sorensen and Taylor (2005b, 2006).

Additionally, we ruled out certain private-sector strategies, such as pay-as-you-drive (PAYD) insurance,³ that would be implemented by firms whose actions are not generally subject to local regulation. We did not consider selective street-widening projects, a useful strategy in many suburban locales, because widening the street is often infeasible in dense urban settings. Likewise, we did not evaluate grade separations for the intersection of roads and rail lines or the possibility of prohibiting freight deliveries in congested areas during certain hours; though promising, we viewed these as being integrally related to goods-movement issues.

We enumerate such examples to make it clear that their omission from our final recommendations is not an indication that they were judged as lacking merit. Rather, they simply fell beyond the defined scope of the study. We also believe that it would be useful to pursue additional research to evaluate the role that some of these omitted strategies might play in improving transportation in Los Angeles.

Strategies Selected for Evaluation

While the criteria just described disqualified certain strategies from further consideration, numerous options could still help to reduce congestion in Los Angeles in the near term. These fall into three broad categories: increasing the efficiency of the existing road network (often referred to as *transportation system management*, or TSM, strategies); reducing peak-hour vehicle travel through incentives, regulations, or pricing (often referred to as *transportation demand management*, or TDM, strategies); and reducing the cost or improving the attractiveness of alternative modes of travel, such as public transit, walking, and biking. In this section, we briefly introduce the strategies in each of these categories; they are discussed in much greater detail in Appendixes B1 through B28.

³ The intent of PAYD insurance is to calculate insurance rates based on the number of miles driven rather than charging a flat rate for the entire year. This provides motorists with a financial incentive to reduce mileage, which, in turn, should have some effect on reducing congestion. See Litman (1997, 2005) for further discussion.

Transportation System Management Strategies

The primary goal of TSM strategies is to use the existing road network as efficiently as possible. Many of the available TSM strategies can be quite effective in reducing congestion in the short term. They also tend to be less politically controversial than many of the demand-reduction strategies, though there are a few exceptions to this rule. On the other hand, TSM strategies often require significant capital or operating expenses. Moreover, because TSM strategies are less likely to raise political opposition, many of them have already been implemented to a significant degree. Finally, TSM strategies are less effective over the longer term—in part because their short-term benefits are subject to erosion through the effects of triple convergence (Downs, 2004), as described in Chapter Two. Specific short-term TSM strategies considered in this study include the following:

- *freeway ramp metering*: using traffic signals at freeway on-ramps to even out the rate at which new vehicles enter the freeway, which, in turn, promotes smoother flow in the main lanes (see Appendix B1)
- *traffic-signal timing and control*: managing the timing of individual signals and coordinating the timing across multiple signals to reduce intersection delays and improve overall travel speeds on the arterial network (see Appendix B2)
- *HOV-lane strategies*: options related to HOV lanes, including the conversion of general-purpose lanes to HOV lanes, altering HOV passenger limits, eliminating clean-air-vehicle exemptions for HOV lanes, and enforcing HOV passenger requirements more strictly (see Appendix B3)
- *park-and-ride facilities*: adding or improving park-and-ride lots to increase utilization of existing HOV lanes and high-capacity transit services (see Appendix B4)
- *officers at intersections*: deploying traffic officers to especially congested intersections during peak travel hours to control the flow of vehicles more effectively and prevent reckless or illegal maneuvers that might cause accidents or lead to gridlock (see Appendix B5)

- *left-turn signals*: reducing the level of congestion resulting from left turns at busy intersections through such tactics as adding or expanding left-turn lanes, adding left-turn signals, changing the timing of left-turn signals, or prohibiting left turns entirely (see Appendix B6)
- *curb-parking restrictions*: eliminating curb parking during peak travel hours to provide additional lane capacity on busy arterial corridors (see Appendix B7)
- *one-way streets*: converting two-way streets to one-way operation to increase lane capacity and enable more-efficient signal timing (see Appendix B8)
- *rush-hour construction bans*: prohibiting construction activity during peak travel to minimize resulting travel delays (see Appendix B9)
- *incident management*: enabling quicker detection, response, and clearing of traffic incidents, such as crashes or breakdowns, to reduce the duration of resulting traffic delays (see Appendix B10).

Transportation Demand Management Strategies

TDM strategies aim to reduce the demand for automotive travel, especially during peak hours. Some TDM options are voluntary, others are enforced through regulations, and still others rely on prices to reduce automotive demand. The strengths and weaknesses of TDM strategies vary depending on which of these three approaches is taken.

While voluntary measures are unlikely to engender political resistance, they are also less likely to produce significant and lasting reductions in automotive travel (Giuliano, 1988). Regulatory approaches can be more effective in the short term, but they are more likely to face political opposition among stakeholder groups affected by the regulations. Moreover, the benefits of regulatory approaches tend to diminish over time based on the effects of triple convergence as well as general growth in demand for travel. Pricing approaches, like their regulatory counterparts, are also likely to face political resistance. As described in Chapter Two, however, their congestion-reduction benefits are sustainable over the long term, and many generate revenue that can be used

to support needed transportation investments. Next, we describe the specific short-term TDM strategies considered in this study.

Voluntary TDM Strategies. We considered the following voluntary TDM strategies:

- *ride sharing*: encouraging and facilitating travelers' ability to form or join carpools or vanpools for frequent trips, such as journeys to and from work (see Appendix B11)
- *telecommuting*: enabling employees to work from home or from some other remote location, to reduce the number of commuter trips to the main office location (see Appendix B12)
- *flexible work hours*: enabling employees to shift their work-hour schedules to avoid driving to and from work during the most congested travel periods (see Appendix B13)
- *car-sharing*: providing a fleet of vehicles that are shared among multiple users, which may reduce individual car ownership and, in turn, aggregate automotive travel (see Appendix B14)
- *traveler-information systems*: providing information, such as real-time traffic conditions, traffic-incident alerts, and suggested route alternatives, to help drivers avoid traveling on the most congested routes or at the busiest times of day (see Appendix B15).

Regulatory TDM Strategies. We considered these regulatory TDM strategies:

- *mandatory TDM programs*: requiring certain employers (often based on size or location) to implement a package of TDM measures (such as ride-sharing programs, telecommuting options, flexible work hours, and transit subsidies) to reduce the number of employees who drive to work during peak hours (see Appendix B16)
- *driving restrictions*: prohibiting certain individuals from driving at certain times or in certain locations in order to reduce aggregate automotive travel (most commonly implemented based on license-plate numbers; for example, vehicles with a license plate ending with the number 9 might be prohibited from driving

in the downtown area or on the freeways every other Thursday during peak hours) (see Appendix B17).

Pricing Strategies. We considered these pricing strategies:

- *HOT lanes*: allowing SOVs to pay a toll for faster travel in the HOV lane; the toll increases during the peak hours to ensure that the HOT lanes remain free-flowing (see Appendix B18)
- *cordon congestion tolls*: delineating a heavily congested area (the cordon zone, often a CBD) and charging vehicles a toll for entering or driving in the area during peak hours as a means of reducing automotive traffic in the zone (see Appendix B19)
- *variable curb-parking rates*: varying the rate for curb parking by time and location to ensure that at least a few spaces are always available, thereby reducing the additional congestion that occurs when drivers circle the block looking for underpriced—and often unavailable—curbside parking (see Appendix B20)
- *parking cash-out*: providing workers whose employers lease parking on their behalf with the option of receiving the cash value of the lease in place of the free parking, thereby providing financial motivation to walk, bike, or take transit instead of driving (see Appendix B21)
- *local fuel taxes*: levying fuel taxes to raise local transportation revenue and simultaneously reduce the demand for automotive travel (see Appendix B22).

Alternative Transportation Strategies

The goal of strategies in this category is to make alternative modes of travel, such as transit, biking, and walking, either cheaper or more attractive. This acts as a complement to the TDM strategies enumerated in the preceding section. Whereas TDM strategies provide a push (through incentives, regulations, or pricing) to reduce driving, the strategies in this category act as a pull to lure travelers to other modes.⁴

⁴ Note that the ride-sharing TDM strategy could also be categorized as an alternative transportation mode. We elected to group it with other TDM measures because employers often implement it in concert with other TDM strategies.

Alternative transportation improvements offer two key benefits: increasing accessibility among those unable to drive and improving the menu of travel options for all travelers. They may prove especially beneficial for individuals from lower-income and minority groups, who are statistically more likely to rely on public transit or other alternative modes (Pisarksi, 2006). To the extent that alternative transportation improvements lead to more walking and biking, they can contribute to improved health outcomes among the population (VTPI, 2008c). Such investments can also foster more vibrant and livable communities (VTPI, 2008a).

Alternative transportation strategies also face limitations. The mode shares for transit, walking, and biking are all quite low, so even dramatic gains (e.g., a doubling in the number of cycling trips) would translate to only a small reduction in driving. Moreover, any congestion-reduction benefits that do occur are subject to the erosive effects of triple convergence (Downs, 2004). Alternative transportation improvements—especially for public transit—can also be costly, and many transit operators already face challenging budgetary constraints. Finally, evidence suggests that walking and biking can be more dangerous than driving in terms of injuries and fatalities per mile of travel, so careful attention to the safety features of pedestrian and cycling improvements is essential (Pucher and Dijkstra, 2000).⁵ Specific short-term alternative transportation strategies considered include public-transit strategies and nonmotorized travel options.

Public-Transit Strategies. We considered the following public-transit strategies:

- *variable transit fares*: varying transit fares by time of day and length of trip to encourage greater transit patronage for shorter trips in the off-peak hours, when available capacity is not fully utilized (see Appendix B23)

⁵ According to Pucher and Dijkstra (2000), the rate of pedestrian fatalities is 36 times higher than that of car-occupant fatalities per mile of travel, while the rate of bicycling fatalities is 11 times higher than car-occupant fatalities on a per-mile basis.

- *deep-discount transit passes*: offering significantly discounted transit passes purchased by employers or other large organizations on behalf of all employees or members; if structured correctly, this can boost transit ridership while increasing net revenues for the transit operator (see Appendix B24)
- *BRT*: implementing such features as bus-only lanes, signal preemption or prioritization, skip-stop service, and headway-based scheduling to make bus transit faster, more reliable, and more convenient (see Appendix B25)
- *bus-route reconfiguration*: revising bus routes and schedules to offer better service given the spatial distribution of patrons (and potential patrons) and the location of major activity centers (see Appendix B26).

Nonmotorized-Travel Strategies. Finally, we considered these strategies related to nonmotorized travel:

- *pedestrian strategies*: encouraging more walking through improved pedestrian infrastructure, safer roadway and intersection designs, traffic-calming techniques, revised signal-timing strategies, and better enforcement of pedestrian-safety laws (see Appendix B27)
- *bicycling strategies*: encouraging more bicycling through improved bike lanes and networks, safer intersections, the provision of bike-storage facilities, improved bicycle access to transit, and citywide bike-rental programs (see Appendix B28).

Congestion-Reduction Strategies in Other Major Cities

In the process of identifying short-term congestion-reduction strategies for potential application in Los Angeles, we examined the efforts of several other major cities, both in the United States and abroad. A prime motivation for this review was to determine whether other cities might have discovered effective approaches that are not yet represented in the research literature. We thus focused specifically on larger cities known for their innovative or aggressive attempts to mitigate traffic

congestion, including Denver, Houston, Miami, Minneapolis, New York, San Francisco, Seattle, Bogota, Curitiba, London, Stockholm, and Singapore.⁶ Our examination of these cities did not reveal any new strategies—that is, strategies not also discussed in the literature. We did, however, observe several general trends relevant to the short-term strategies considered in this study and worthy of note.

Most of the cities employ a combination of measures to use their roads as efficiently as possible, reduce peak-hour automotive travel, and improve transit. The fact that this is the rule rather than the exception suggests that efforts to reduce congestion and improve mobility and accessibility may benefit from a broad range of tools and approaches.

Most of the cities employ advanced TSM strategies, such as ramp metering and automated signal-timing and control. Though such systems may require considerable investment, they are also less likely to face political opposition than many of the more aggressive demand-reduction strategies. This may explain the relatively uniform application of leading TSM approaches among major cities.

Most of the cities have developed BRT systems. Motivated by the success and cost-effectiveness of the extensive BRT systems in Bogotá and Curitiba, a majority of the cities we reviewed—all but two—have already implemented BRT features or are planning to do so in the future.

All of the cities have implemented aggressive approaches to reduce demand. Absent complementary efforts to discourage automotive travel, effective TSM and transit services cannot stem congestion in the long run (Downs, 2004). Many cities—including all of those that we examined—have thus implemented aggressive steps to reduce the demand for driving, including mandated employer TDM programs, driving restrictions, and pricing.

Few cities have instituted mandatory employer trip-reduction programs, which appear to face challenging political obstacles. Though mandatory TDM programs can be effective (Giuliano, Hwang, and Wachs,

⁶ These cities were selected based on references in the literature, Web-based research, and suggestions offered by knowledgeable transportation experts and local officials with whom we spoke.

1993), very few of the cities we reviewed have required existing employers to implement such programs.⁷ In several cities, including Houston and San Francisco, mandatory employer TDM programs were at one point instituted and then subsequently repealed (this occurred in Los Angeles as well). One interpretation is that employers, who must shoulder the cost of implementing such programs, represent a powerful stakeholder group capable of organizing opposition to this type of strategy. Los Angeles is a case in point, where opposition in the business community in the mid-1990s led to the repeal of AQMD's Regulation XV and subsequent state legislation prohibiting local jurisdictions in California from enacting mandatory employer trip-reduction programs (Giuliano and Hanson, 2004; Snyder, 2007).⁸

Few cities have implemented driving restrictions, in part because they have not proven successful where applied. Among the cities we examined, Curitiba and Bogotá are the only two that have implemented driving restrictions, and both of these cities have comparatively low auto-ownership rates and very effective BRT systems (Ardila Gómez, 2004). Available evidence indicates that driving restrictions have been largely ineffective in reducing traffic in the longer term and can lead to undesirable side effects (NYC Traffic Congestion Mitigation Commission et al., 2007).⁹ As they would require motorists to change their behavior, driving restrictions are likely to engender political opposition as well. These factors help to explain why the strategy has not been employed more widely.

⁷ It is more common for cities to require that new developments include TDM programs as part of the real-estate-approval process.

⁸ Regulation XV required all work sites in the region with more than 100 employees to institute TDM programs. Regulation XV was succeeded by Regulation 2202, which applies only to firms with more than 250 employees and provides the option of either instituting TDM programs or contributing funding to other air-quality-management programs implemented by AQMD.

⁹ When license plate-based driving restrictions were implemented in Mexico City, for instance, many households purchased additional vehicles so they could still drive every day. Because many of the supplementary vehicles were older and more polluting, air quality deteriorated while traffic congestion did not improve (Eskeland and Feyzioglu, 1997).

Most of the cities have implemented some form of pricing strategies or are developing plans to do so. Pricing approaches, like other aggressive TDM measures, are likely to face political hurdles, and they may introduce equity concerns as well. Yet judging from our review of these cities, pricing strategies appear to be gaining more adherents. To date, cities in the United States have focused primarily on HOT lanes and other facility-based congestion-tolling applications. Large-scale cordon tolls have thus far been limited to international cities, though San Francisco and New York have explored this approach as well. One explanation for why pricing applications are becoming more common is that existing examples have proven extremely effective in reducing traffic delays, both over the short term and in the longer term. Perhaps of equal importance, pricing strategies can generate significant revenues to fund needed transportation investments. With many cities facing a widening gap between transportation budgetary demands and available funding sources, the revenue-generating potential of pricing approaches appears to be stimulating a greater willingness on the part of elected officials to consider this set of strategies (Sorensen and Taylor, 2005a).

Strengths and Limitations of Individual Strategies

A core element of our analysis was to assess the advantages and drawbacks of the individual strategies selected for evaluation. In this section, we briefly introduce the evaluation framework and then summarize the results of our strategy assessments. Our short-term recommendations for reducing traffic congestion in Los Angeles, presented in the next chapter, draw on these assessments.

Strategy-Assessment Framework

When considering the potential utility and feasibility of alternative congestion-reduction strategies for Los Angeles, there are many relevant factors to evaluate. How much will the strategy cost to implement (or, for revenue-producing strategies, how large will the net revenues be)? How effectively will the strategy reduce congestion in the near term,

and will the benefits persist over the longer term? How will the strategy influence other relevant social goals? Will the strategy face significant implementation obstacles? To what extent has the strategy already been implemented in Los Angeles? Reflecting on such questions, our strategy-assessment framework included the following elements:

- net cost/revenue implications
- short-term effectiveness in reducing congestion
- long-term effectiveness in reducing congestion
- accessibility, mobility, and traveler choice
- safety
- economic efficiency
- environment
- equity
- stakeholder concerns
- general political obstacles
- institutional or jurisdictional challenges
- current implementation in Los Angeles.

We evaluated each option at the strategic level rather than examining project-specific details, and the analysis (given budgetary constraints) did not include formal modeling. We thus found it necessary to develop qualitative ratings for characterizing each strategy with respect to the criteria just outlined.¹⁰ For example, rather than asserting that a cordon congestion toll in Los Angeles will raise a specific amount of money, we might instead assess the strategy as being likely to produce *high* net revenues. Note that a full discussion of our methodology for assessing the strategies is provided in Appendix A; here, we highlight a few key elements of the methodology that may assist in interpreting the summary results presented next.

- *Evidence base:* Though qualitative, our ratings are based on available evidence. Sources included findings from the research lit-

¹⁰ Quantified outcomes could be estimated only in the context of specific implementation proposals, and evaluating such proposals fell beyond the scope of our study.

erature, agency evaluations of prior project implementations in Los Angeles, and interviews with knowledgeable staff at local, regional, and state agencies operating in the L.A. region.

- *Scope of implementation:* When considering the potential effects of a given strategy, we assumed that the strategy would be thoughtfully planned and competently implemented in appropriate contexts throughout the region. To illustrate, our ratings for the HOT-lane strategy do not reflect the likely results of implementation on a single freeway, but rather consider the development of a network of HOT lanes spanning the freeway system.
- *Modified ratings:* In cases in which a strategy performs poorly with respect to a specific criterion and a complementary measure for mitigating the problem can be easily implemented, we assumed that the complementary measure would be incorporated and modified the rating accordingly. For example, proposals to institute variable curb-parking prices may engender resistance among local retailers concerned that higher parking charges will drive away their customer base. Shoup (2005) demonstrated, however, that, if a portion of the increased meter revenue is returned to surrounding businesses for the purpose of investing in improved public amenities, local merchants will view the concept much more favorably. We therefore assumed that at least a portion of the revenue would, in fact, be returned to local businesses and reduced the rating for anticipated stakeholder concerns accordingly.
- *Uncertainty:* In certain cases, we could not find evidence describing how a strategy would likely perform with respect to a given criterion. In other instances, the performance might rest on exogenous factors (such as the future price of fuel or decisions by other agencies not involved in the planning and implementation of the strategy). Our approach in such situations was to select the rating that appeared most likely, but also to explicitly describe it as being uncertain. Uncertainty flags are included in the appendixes though not in the rating summary in Figure 5.1.
- *Interpretation of the cost/revenue rating:* We developed a rough guideline for this rating as follows. Net annualized costs or revenues on the order of hundreds of millions of dollars were described

as *high*, net annualized costs or revenues on the order of tens of millions of dollars were described as *medium*, and net annualized costs or revenues on the order of millions or hundreds of thousands of dollars were described as *low*. Anything less than this (in absolute terms) would be described as *neutral*.

- *Interpretation of the short- and long-term congestion-reduction ratings:* Our short-term rating reflects judgments about likely changes to status quo traffic conditions. Thus, a rating of *low* would indicate modest reductions to the current level of congestion, whereas a rating of *high* indicates more-significant short-term reductions in congestion. For the longer-term rating, we considered the effects under the assumption that congestion, absent policy intervention, would continue to grow over time. This alters the interpretation of the ratings. Over the longer term, a rating of *low* indicates that the strategy will reduce the rate at which congestion worsens, a rating of *medium* indicates that the strategy will halt the growth in congestion and maintain current conditions, and a rating of *high* suggests that a strategy could reverse the trend and produce longer-term declines in congestion relative to the present.

Strategy-Assessment Results

The results of our strategy assessments are synthesized in Figure 5.1. To reduce the complexity, we have aggregated several of the individual criteria into composite ratings. Specifically, “Other Social Goals” combines the individual ratings for safety, economic efficiency, environmental, and equity effects. “Implementation Obstacles,” in turn, combines the individual ratings for stakeholder concerns, general political obstacles, and institutional or jurisdictional challenges.¹¹ See Appendix A for more details on the construction of the composite ratings.

The following general observations emerge from the strategy-assessment summary presented in Figure 5.1.

¹¹ Note that the higher level of uncertainty applies only to our two composite ratings, “Performance on Other Social Goals” and “Implementation Obstacles.” The higher level of uncertainty indicates that two or more of the individual ratings combined in the composite rating were considered uncertain.

Most strategies face some limitations. As suggested in Chapter Two, few options are simultaneously effective, inexpensive, and unlikely to face significant implementation obstacles (Downs, 2004; Giuliano and Hanson, 2004). This means that there will be inevitable trade-offs to consider in developing specific strategy recommendations for Los Angeles. We return to this consideration in the next chapter.

Only pricing strategies remain effective over the longer term. The majority of strategies ranked as offering moderate or significant short-term congestion-reduction potential are assessed as offering lower potential over the longer term. This is a direct result of the effects of triple convergence described by Downs (2004).

Many strategies perform well on other transportation goals. Even though few of the strategies offer compelling longer-term congestion-reduction benefits, many perform well with respect to enhancing overall mobility, accessibility, or traveler choice. For example, though our research indicates that transit improvements will have little effect in reducing traffic, they will improve accessibility and traveler choice. And though triple convergence and longer-term growth in travel demand may slowly erode the congestion-reduction effects of improved signal timing and control, the strategy will still enable the arterial network to move more vehicles overall.

Many strategies rate highly on other social goals. In part, this is because congestion itself contributes to a range of negative social outcomes, such as wasted time and fuel and excess emissions of air pollutants. Reducing congestion, even to a small degree, will therefore tend to improve these outcomes. An encouraging implication of this finding is that few of the considered strategies would need to be ruled out based on poor performance toward other social goals.

Easier strategies have already been implemented. Though not uniformly the case, there appears to be an inverse relationship between the anticipated level of implementation obstacles and the degree to which a strategy has already been applied in Los Angeles. That is, strategies facing greater implementation obstacles are less likely to have been applied widely, and vice versa. While not unexpected, this underscores the importance of finding ways to overcome anticipated political or institutional obstacles in order to implement some of the most

Figure 5.1
Overview of Strategy Assessments

Strategy	Public-Sector Cost/Revenue Implications	Short-Term Congestion Reduction	Long-Term Congestion Reduction
	High cost High revenue	Negligible High	Negligible High
TSM strategies			
Freeway ramp metering			
Signal timing and control			
HOV lane strategies			
Park-and-ride facilities			
Officers at intersections			
Left-turn signals			
Curb-parking restrictions			
One-way streets			
Rush-hour construction bans			
Incident management			
Voluntary TDM			
Ride-sharing			
Telecommuting			
Flexible work hours			
Car-sharing			
Traveler information systems			
Regulatory TDM			
Mandatory TDM programs			
Driving restrictions			
Pricing			
HOT lanes			
Cordon congestion tolls			
Variable curb-parking rates			
Parking cash-out			
Local fuel taxes			
Public transit			
Variable transit fares			
Deep-discount transit passes			
BRT			
Bus route reconfiguration			
Nonmotorized Travel			
Pedestrian strategies			
Bicycle strategies			

Figure 5.1—Continued

Strategy	Other Transportation Goals	Other Social Goals	Implementation Obstacles	Current Implementation in Los Angeles
	Very bad Very good	Very bad Very good	High Low	None Advanced
TSM strategies				
Freeway ramp metering				
Signal timing and control				
HOV lane strategies				
Park-and-ride facilities				
Officers at intersections				
Left-turn signals				
Curb-parking restrictions				
One-way streets				
Rush-hour construction bans				
Incident management				
Voluntary TDM				
Ride-sharing				
Telecommuting				
Flexible work hours				
Car-sharing				
Traveler information systems				
Regulatory TDM				
Mandatory TDM programs				
Driving restrictions				
Pricing				
HOT lanes				
Cordon congestion tolls				
Variable curb-parking rates				
Parking cash-out				
Local fuel taxes				
Public Transit				
Variable transit fares				
Deep-discount transit passes				
BRT				
Bus route reconfiguration				
Nonmotorized Travel				
Pedestrian strategies				
Bicycle strategies				

NOTE: HOT = high-occupancy toll.

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promising strategies that have yet to be applied in Los Angeles. We consider this at greater length in Chapter Seven.

Summary

The goal in this chapter was to identify a set of short-term congestion-reduction strategies for potential application in Los Angeles and assess their strengths and limitations. We began by reviewing the academic literature, examining prior programs and proposals in Los Angeles, and exploring approaches currently being pursued in other major cities. Among the options identified, we focused on strategies that (1) could be implemented and produce significant effects in a period of roughly five years or less, (2) could be implemented or influenced through the actions of local government, and (3) would apply to all types of traffic (we did not include strategies with an exclusive focus on goods movement).

Based on our initial search and selection criteria, we arrived at a total of 28 potential short-term traffic-reduction strategies for Los Angeles. These include TSM strategies to use existing roadway capacity more efficiently, TDM strategies intended to reduce peak-hour automotive travel, and strategies designed to increase the attractiveness of alternative transportation modes.

Our review of the approaches being pursued in other major cities indicates that most have employed a broad suite of strategies spanning TSM, TDM, and alternative transportation improvements. The majority of cities we examined have implemented advanced TSM measures, such as ramp metering and signal timing and control. Many cities, motivated by the early success of Curitiba and Bogotá, have also adopted BRT strategies or are planning to do so. All of the cities, finally, have also adopted one or more strategies to achieve direct reductions in the demand for driving. Several U.S. cities have instituted municipal mandates for employers to create TDM programs—though, in a few cases, these have been repealed—while both Bogotá and Curitiba have implemented some form of driving restrictions. The majority of the cities in our review, however, have either implemented pricing to

reduce peak-hour demand or are planning to do so. Pricing has proven effective where implemented and can raise significant transportation revenue.

To determine the strengths and limitations of alternative strategies for achieving short-term reductions in congestion in Los Angeles, we evaluated each of the options against a broad set of criteria, including cost/revenue implications, short- and longer-term effectiveness in reducing congestion, potential to support other transportation goals, potential to support other social and environmental goals, likely implementation obstacles, and current level of implementation in Los Angeles.

Several broad observations emerged from this analysis. First, few options are without limitations: Most are ineffective, costly, or likely to face significant implementation obstacles. Of the many options considered, most are likely to be ineffective in reducing congestion over the longer term; pricing strategies are the only exception to this rule. On the other hand, many of the strategies do offer other transportation benefits—improved mobility, accessibility, or traveler choice—and support other social goals as well. Finally, many of the easier strategies have already achieved a high level of implementation in the region. The greatest opportunities thus lie with strategies that are either costly or, more often, likely to engender significant political opposition.

Short-Term Congestion-Reduction Recommendations

Our purpose in this chapter is to develop a set of specific short-term transportation-planning and -policy recommendations for Los Angeles based on the findings presented in the preceding chapters. We begin by outlining our methodology for selecting strategy recommendations, which proceeds in two stages: (1) developing a guiding policy framework for reducing congestion and improving transportation in Los Angeles and (2) identifying the strategies that best support this framework, leading, in turn, to a set of specific recommendations.

In the first stage of the analysis, we revisit several key lessons and insights from earlier chapters about the general phenomenon of congestion and the specific contextual challenges faced in Los Angeles. This enables us to outline, in broad strokes, a guiding policy framework that would appear to offer the greatest prospects for reducing traffic congestion, improving transportation alternatives, and promoting other social goals in Los Angeles. The framework consists of the following three integrated policy aims:

- relying on pricing to manage peak-hour automotive-travel demand and raise needed transportation revenue
- significantly improving public transit and other alternative modes
- continuing to improve the efficiency of the road network but with a shift in emphasis from moving vehicles to moving people.

In the second stage, we consider which of the specific strategies evaluated in the previous chapter—either individually or by mutually

reinforcing one another—promise to be most effective in achieving the aims of the guiding policy framework. The individual strategy ratings presented in Chapter Five inform the effort, which draws on the more-detailed strategy discussions contained in the appendixes. Our analysis of the available strategies—in light of their strengths and weaknesses and in the context of the broader integrated policy framework—leads us to a set of 13 recommendations. While the majority of these are unambiguously compelling and can be pursued without delay, several either require additional research or depend on how certain events unfold. We therefore further subdivide the 13 recommendations into a group of 10 primary recommendations and another group of three contingent recommendations (see Table 6.1).

Table 6.1
Primary and Contingent Recommendations

Recommendation Type	Recommendation
Primary	1. Upgrade signal timing and control where deficient.
	2. Restrict curbside parking on all busy arterials.
	3. Convert selected arterials to one-way operation.
	4. Promote ride-sharing, telecommuting, and flexible work schedules.
	5. Develop a network of HOT lanes on the freeway system
	6. Implement variable curb-parking rates in commercial centers.
	7. Enforce employer-parking cash-out in cities.
	8. Develop and aggressively market deep-discount transit-fare programs.
	9. Expand BRT with dedicated arterial and HOT lanes.
	10. Develop an integrated, regionwide bicycle network.
Contingent	11. Evaluate incident management on the arterial network.
	12. Evaluate cordon tolls around major activity centers.
	13. Institute local fuel taxes at the county level.

For each of these, we discuss the motivation for including the strategy, cite key supporting evidence, describe likely implementation obstacles, and outline initial and follow-on implementation steps. We also list the government agencies that would likely play a role in implementing each of the recommendations. For strategies not included in our recommendations, we briefly describe the relative limitations that led to their omission. In the closing section, we speculate on the likely effects of implementing the strategies in Los Angeles and consider how those effects would be distributed through different types of areas (e.g., urban versus suburban) and across different types of facilities (e.g., highways versus arterials). We also summarize the key interactions and complementarities among the 13 recommendations, highlighting the importance of employing a comprehensive and multi-pronged approach to reducing traffic congestion and improving transportation options in Los Angeles.

Approach for Developing Strategy Recommendations

Selecting recommendations and, in particular, choosing whether to include certain strategies at the margin, proved a challenging task. Figure 5.1 in Chapter Five presented a summary of our efforts to assess each of the 28 strategies against a broad range of potentially relevant criteria. In the pursuit of strict objectivity, one might envision a mathematical formula that would be able to determine, based on the criteria ratings, a rank ordering among the 28 strategies considered. One could then select, say, the 10 highest scoring and treat them as recommendations.

Such an approach would have proven problematic, though. To begin with, our ratings are qualitative, implying an inherent degree of judgment and imprecision that would undermine the legitimacy of any simple, formula-based analysis. In addition, comparing one strategy to another based strictly on their ratings would require assumptions regarding the relative importance of different criteria. For instance, is a high score on congestion reduction more important than a high score on cost, more important than performance toward other transporta-

tion goals, or more important than social outcomes? Opinions as to the appropriate weighting for different policy aims are likely to vary widely among different segments of society, and, as a result, there is no obvious “right” set of factors to apply. Finally, the benefits of a particular strategy may depend not only on how the strategy performs in isolation, but also on its interaction with other strategies employed in tandem. It would be difficult to factor such potential interactions into a formal strategy-ranking system that focuses on each strategy in isolation.

Given such challenges, our selection of strategy recommendations, of necessity, required qualitative analysis, interpretation, and judgment. To provide a logical structure for this analysis, we devised a two-stage process for the consideration and selection of strategies. Our first task was to outline, in broad strokes, a guiding policy framework that would offer the greatest prospects for reducing congestion and improving transportation options in the context of Los Angeles. This stage of the analysis was informed by the insights and observations about the general nature of congestion from Chapter Two as well as the specific challenges faced in Los Angeles described in Chapters Three and Four.

With the guiding framework in place, our next task was to identify the subset of strategies that would best support, individually or in combination with one another, the broader policy aims of the framework. Here, we relied on our assessments of each strategy’s strengths and limitations, as well as their current state of implementation in Los Angeles, as presented in Figure 5.1. We also considered the potential interactions among the strategies—that is, the degree to which different strategy options might either complement or undermine one another—based on the detailed discussions provided in Appendixes B1 through B28.

From this analysis, a total of 13 recommendations emerged. Some, in our judgment, are unambiguously compelling, offering benefits that far exceed costs, and can be pursued without delay. Others appear to be promising but either could benefit from additional research or depend on the outcome of events currently unfolding. To distinguish between these kinds of cases, we divided our recommendations into

two sets, including 10 primary recommendations and three contingent recommendations.

Though our methodology was designed to provide a logical and consistent framework for assessing and recommending strategies, we recognize that the qualitative nature of the analysis still allows room for subjectivity and interpretation. Other transportation experts, presented with the same information, might arrive at a different set of final recommendations, though we suspect that there would be much overlap. Given the potential for differences of opinion, we consider it important to be as transparent as possible about the assumptions and evidence that guided our specific choices. Accordingly, as we develop and present our recommendations in the remainder of this chapter, we are also careful to document (1) the observations, lessons, and insights that informed the development of our guiding policy framework; (2) the logic for comparing individual strategies in the context of the policy framework; (3) the specific factors motivating each of the final recommendations, including their individual traits as well as their interactions with other strategies; (4) the logic for distinguishing between primary and contingent recommendations; and (5) the relative limitations of the remaining strategies that led us to omit them from the final list of recommendations.

Developing an Integrated Policy Framework

In earlier chapters, we described the nature of congestion—how it arises, how it behaves, and how it can be reduced—and discussed some of the specific congestion-related challenges faced in the L.A. region. We begin this section by revisiting some of the key findings and observations from these earlier chapters, focusing specifically on the implications for designing effective transportation policy in the region. Based on this analysis, we then put forward a set of integrated policy approaches that appears to offer the greatest prospects for reducing congestion in Los Angeles, both over the short and longer terms, while supporting other transportation and social-policy objectives.

Key Observations on Congestion in Los Angeles

Congestion is a challenge faced by all major cities, and the specific characteristics of urban form in Los Angeles exacerbate the difficulties. To inform the development of a suitable policy response to increasing congestion in the region, it is helpful to synthesize some of the key observations and findings presented earlier in this book.

Absent aggressive intervention, congestion will likely worsen.

Congestion results from an imbalance in the supply of and demand for road space. For several reasons—including diminished fiscal capacity and resistance among affected communities—significant expansion of the existing road network is unlikely. Notwithstanding the current economic downturn and run-up in fuel prices, meanwhile, forecasted growth in population, the economy, and goods movement (see Figures 2.2 and 2.4 in Chapter Two), suggest that automobile and truck travel will continue to expand over the longer term. Given the nonlinear relationship between traffic volume and travel speed (see Figure 2.7 in Chapter Two), even small increases in peak-hour driving could make congestion in Los Angeles much worse.

Actively managing the demand for peak-hour automotive travel offers the greatest potential for reducing congestion in Los Angeles.

Los Angeles already has a very dense road network (see Figure 4.1 in Chapter Four) that is operated at a high level of efficiency (Schrank and Lomax, 2007; see also the “Current Implementation in Los Angeles” column in Figure 5.1 in Chapter Five). Significant opportunities to expand or enhance the efficiency of the road network are therefore unlikely. On the other hand, residents of Los Angeles drive a lot relative to the region’s population density (see Figure 4.3 in Chapter Four). Finding ways to manage the demand for driving during peak hours thus appears to be the most promising—indeed, perhaps the only realistic—way to reduce congestion.

Only pricing strategies remain effective in managing automotive travel demand over the longer term. While several of the available TDM and transit strategies may help to reduce peak-hour automotive travel in the short term, only pricing strategies are resistant to the effects of triple convergence (Downs, 2004) in which travelers converge on newly freed capacity from other modes, other routes, and other times

of day. The application of prices, which helps to alleviate congestion in the first place, also acts as a deterrent to triple convergence. Another way of describing this concept is that pricing is the only approach that can reduce congestion without inducing additional travel demand. Provided that prices are allowed to rise, as needed, in response to general increases in the demand for automotive travel in future years—that is, that prices remain a function of demand rather than being set by administrative decree—then pricing strategies will continue to be effective in reducing congestion over the longer term as well.

Given the fact that automotive-travel demand in Los Angeles is likely to expand with continued growth in population, the economy, and trade, the longer-term effectiveness of pricing represents an especially compelling benefit. Pricing will also generate revenue that can be used to fund complementary strategies.

Pricing strategies require alternative transportation improvements. Because pricing strategies increase the financial cost of traveling during peak hours, at least some drivers will likely shift to public transit or other modes.¹ Absent high-quality transit alternatives—options that are fast, convenient, safe, and efficient—pricing will create equity concerns, especially among lower-income drivers. While Los Angeles has, in recent decades, invested in subways, light rail, and BRT, our research suggests that the region—relative to its density and in comparison with other major metropolitan areas in the country—is not yet a leader in the provision of faster transit options with dedicated right-of-way (see Figure 4.4 in Chapter Four). Strategic expansions to the existing rail network may, in some cases, be merited over the longer term; in the near term, many BRT features can be applied to improve the speed and convenience of bus service in the region—at lower cost and with faster implementation.

The density of Los Angeles also argues for improved alternatives. Using prices to reduce peak-hour congestion is not the only argument for improving transit and other alternative modes in the region. Los Angeles is very dense at the regional level (see Table 4.3 in Chapter

¹ Other drivers may choose to pay the congestion toll, drive at different times or by different routes to avoid or reduce the toll, or forgo their trip entirely.

Four), and density makes it more difficult to preserve unfettered automobile. On the other hand, greater density makes alternative modes more feasible and cost-effective.² Whether or not the region implements pricing to manage peak-hour automotive demand, investing in improved alternative transportation will yield important benefits. If Los Angeles implements pricing strategies, improved alternatives will help mitigate any equity concerns that arise. If Los Angeles does not implement pricing—in which case congestion will almost certainly worsen in the coming decades—improved transit and other options will provide valued alternatives for those wishing to avoid driving in peak-hour congestion.

Integrated Policy Objectives for Los Angeles

From these considerations, we could develop an integrated framework for transportation policy that is (1) capable of achieving lasting reductions in congestion while improving alternative modes, (2) consistent with the specific challenges and opportunities in Los Angeles, and (3) broadly supportive of other social goals in the region. There are three principal elements:

- *Relying on pricing to manage peak-hour automotive demand, raise needed revenue, and promote more-efficient use of existing capacity:* Pricing will reduce congestion by managing the demand for peak-hour automotive travel, and it will remain effective over both the short and longer terms. Pricing will also raise revenue to fund needed transportation improvements. Finally, certain forms of pricing, such as HOT lanes, will enhance the throughput capacity of existing facilities as an additional benefit.
- *Significantly improving transit and other alternative modes:* Making alternative transportation faster and more convenient will help reduce any equity concerns that arise with pricing and will benefit

² In denser environments, origins and destinations are closer together, making it possible to walk, bike, or ride transit for a greater share of trips. Higher density also increases the number of potential patrons living or working in walking distance of a transit stop, thus enabling greater returns on transit improvements.

those in the region who already travel by modes other than private automobile.³

- *Continuing to improve the efficiency of the road network but with a shift in emphasis from moving cars to moving people:* While Los Angeles has already implemented many TSM measures, our research suggests that there are still opportunities for improvement. Where further investments would result in net benefits, they should be made. From a policy perspective, however, the critical issue here is the shift in focus from moving cars to moving people. This implies, for instance, that, if an arterial lane can carry more passengers as a bus-only lane than as a mixed-flow lane, it should be converted to bus-only operation. This idea, developed in San Francisco and elsewhere, is often described as a *transit-first priority*, though it may be more accurate to think of it as a *people-first priority*.

Selecting Strategies to Support the Integrated Policy Framework

With the integrated policy framework in place, the next stage in our analysis was to consider the potential of different strategies in supporting the broad goals expressed in the framework—managing the demand for peak-hour automotive travel, boosting transportation revenue, improving transportation alternatives, and using existing road capacity more efficiently. To be considered for inclusion in the recommendations, a strategy should be effective in fostering at least one of these objectives, though certain strategies might simultaneously support multiple goals.

The assessments of the strengths and limitations of the available strategies, summarized in Figure 5.1 in Chapter Five and discussed in

³ It may, in fact, prove necessary to implement significant transit enhancements before aggressive forms of pricing, such as cordon tolls, will be politically viable. In February 2005, voters in Edinburgh, Scotland, soundly defeated a proposal to implement a cordon toll similar to that in London, in part because the transit options for traveling to the city center were considered insufficient (Dalton, 2005).

greater detail in Appendixes B1 through B28, were instrumental in this evaluation. Note, however, that the relative emphasis placed on different assessment criteria depended in part on the policy aim that a given strategy might support. The following points summarize our application of the criterion assessments in evaluating the prospects for the different available strategies:

- For strategies intended to achieve sustainable reductions in peak-hour congestion and raise revenue (i.e., pricing strategies), key criteria included short- and longer-term effectiveness in reducing congestion along with cost/revenue implications.
- For strategies intended to improve transportation alternatives, key criteria included performance toward other transportation goals—most notably, the element of traveler choice—and cost/revenue implications. As argued earlier, alternative transportation improvements are not, on their own, expected to achieve significant reductions in congestion—in part due to the phenomenon of triple convergence and in part due to the fact that most alternative transportation options have very low mode share to begin with. For this reason, we placed less emphasis on the ratings for short- and longer-term congestion-reduction effects.
- For strategies to foster more-efficient use of existing capacity, key criteria included short-term effectiveness in reducing congestion, support for other transportation goals, and cost/revenue implications. The rating for longer-term effectiveness in reducing congestion was deemphasized, given that the congestion-reduction effects for TSM measures are expected to erode over time with triple convergence and longer-term growth in travel demand.
- For all strategies, the criterion of performance on other social goals was considered. Yet the vast majority of the strategies performed well, or at least not poorly, with respect to this rating, so there was little need to rule out specific strategies on the basis of other social goals.
- For all strategies, we also considered the existing degree of implementation in Los Angeles. For strategies that offer modest benefits but have already achieved a moderate or significant level of invest-

ment, additional efforts are likely to yield diminishing returns. Note that this issue proved to be especially salient for the TSM measures and voluntary TDM measures; because such strategies tend to be less controversial, many have already received considerable attention in recent years.

- For all strategies, we considered the rating for likely implementation obstacles as well. All else equal, a strategy with lower obstacles would be considered preferable to one with higher obstacles. That said, we did not rule out strategies strictly on the basis of implementation challenges, given that many of the most promising options are indeed likely to face controversy. Rather, we considered the implementation-obstacle rating to be an indicator of whether complementary efforts would be required to mitigate concerns or build political consensus.

A final consideration that informed our selection process was the potential interactions among multiple strategies, the manner in which various options might either support or undermine one another. Here, we drew on material in the detailed strategy evaluations provided in Appendixes B1 through B28, each of which contains a section discussing the interactions with other strategies. Note that these interactions do not appear in the strategy summary in Figure 5.1 in Chapter Five; capturing all of the possible pair-wise interactions among 28 distinct strategies in a single, comprehensible table was not deemed feasible. In the discussion of our recommendations, we do, however, highlight some of the more important interactions that influenced the selections. We also summarize the interactions among our recommendations in the closing section of this chapter.

Through this logic, we arrived at a total of 13 integrated recommendations. It should be noted that one recommendation represents a combination of three distinct strategies, so, in fact, our recommendations span 15 of the original 28 strategies considered. This breadth reflects that congestion remains a complicated challenge and that efforts to solve this challenge can benefit from a multipronged approach.

Among the 13 recommendations, 10 appear unambiguously compelling—offering benefits that easily exceed costs—and can be

pursued without delay. These are described as our primary recommendations. The three remaining recommendations also appear quite promising but are subject to some uncertainty; either they require additional study or they depend on the outcomes of events currently unfolding in Los Angeles. We thus describe these as our contingent recommendations.

Strategy Recommendations

Table 6.2 presents, in summary form, our 13 recommendations. The table also indicates the principal goal(s) from the integrated policy framework that each recommendation is intended to support. The table lists the primary recommendations first, followed by the contingent recommendations. Note that we have not attempted to prioritize further among the recommendations in each of the two broad categories; rather, the order of presentation simply follows the sequence from Chapter Five: TSM measures followed by TDM measures (including pricing) followed by alternative transportation measures.

In the remainder of this section, we present our 10 primary and three contingent recommendations in greater detail. For each, we discuss the primary motivations for their inclusion, highlight key evidence of their utility, and discuss implementation obstacles that they are likely to face in the L.A. context. We also suggest implementation steps, distinguishing, where needed, between initial and follow-on implementation activities. After describing each of the recommendations, we also provide a table that summarizes the likely roles of different agencies and entities in their implementation.

Primary Strategy Recommendations

Recommendation 1: *Prioritize and fund investments in upgraded signal timing and control in cities where the current technology is deficient, coordinate signal timing between jurisdictions, and ensure that newly installed technology enables signal prioritization for BRT.*

- **Motivation:** Improving the timing and control of traffic signals can lead to significant reductions in delays at arterial intersections, and many cities in the region—most notably, the city of Los Angeles—have already invested heavily in this approach. Yet cities in the county with fewer resources often rely on outdated and much less effective timing and control mechanisms, contributing to congestion on the arterial network. Additionally, signal timing and control is often uncoordinated between cities, leading to bottlenecks at city boundaries. Upgrading signal timing and control technology and improving interjurisdictional coordination will help to reduce delays and will also create the opportunity to implement signal prioritization for faster bus service.
- **Supporting evidence:** A comprehensive study sponsored by the Federal Highway Administration (FHWA) found that the incorporation of advanced signal systems can increase travel speeds by 14 to 22 percent and reduce travel times by 8 to 15 percent (MITRE, FHWA, and USDOT, 1996). When the City of Los Angeles synchronized the signals along Olympic, Venice, and Victory Boulevards in 2004, average traffic speeds along these routes increased by 10 to 20 percent, while average travel times were reduced by 14 to 17 percent (LADOT, undated[b]).
- **Implementation obstacles:** The primary obstacle is funding, as the acquisition and installation of signal timing and control technology are very expensive. The cost of a new single-signal installation is reported to range between \$75,000 and \$175,000, depending on the sophistication of the technology. As another illustration of the expense, the City of Los Angeles recently received \$150 million for traffic-signal synchronization improvements from state bond revenues. This will enable LADOT to add 1,117 signals to its current signal-control system, upgrade an additional 1,256 signals to the most recent technology, and add 340 traffic-tracking cameras to help monitor intersections.
- **Initial implementation steps:** Signal timing and control is most deficient in cities that lack the resources to invest in the latest technology. We therefore recommend that this effort be funded and coordinated at the county level, likely by Metro. The initial

**Table 6.2
Strategy-Recommendation Objectives**

Recommended Strategy	Manage Peak-Hour Automotive Travel	Raise Transportation Revenue	Improve Alternative Transportation Options	Use Existing Capacity More Efficiently
Primary recommendations				
1. Improve signal control and timing where deficient			○	●
2. Restrict curb parking on busy thoroughfares			○	●
3. Create a network of paired one-way streets			○	●
4. Promote ride-sharing, telecommuting, and flexible work schedules	○		●	
5. Develop a network of HOT lanes	●	○	●	●
6. Implement variable curb-parking rates in commercial centers	●	●		●
7. Enforce parking cash-out law at the municipal level	●			
8. Promote deep-discount transit passes		○	●	
9. Expand BRT with bus-only lanes			●	

Table 6.2—Continued

Recommended Strategy	Manage Peak-Hour Automotive Travel	Raise Transportation Revenue	Improve Alternative Transportation Options	Use Existing Capacity More Efficiently
10. Implement a regionally connected bicycle network			●	
Contingent recommendations				
11. Evaluate incident management for the arterial network				●
12. Evaluate potential applications of cordon congestion tolls	●	●		○
13. Levy local fuel taxes to raise transportation revenue	○	●		

NOTE: ○ = additional goal that a recommendation may help support. ● = a primary goal that a recommendation is intended to accomplish.

implementation steps would include (1) conducting a countywide survey of existing signal technology and current traffic conditions on the arterial network so as to prioritize investments and (2) identifying or developing a revenue stream to fund these investments.

- **Follow-on implementation steps:** Follow-on steps would include the provision of priority-based funding and technical assistance to cities for the installation and integration of signal timing and control technology. As a condition for receiving this assistance, we would also recommend that cities be required to support efforts to coordinate signals at municipal boundaries and allow for signal prioritization to support more-effective BRT service.

Recommendation 2: *Restrict peak-hour curb parking on all congested thoroughfares and dedicate the additional capacity to bus-only lanes where merited.*

- **Motivation:** Prohibiting curb parking on congested thoroughfares during the peak hours can reduce delays by increasing available lane capacity at negligible cost. We recommend restricting curb parking on all major arterial corridors throughout the region subject to recurring congestion and actively enforcing the restrictions (through prompt ticketing and towing) to ensure their effectiveness. In corridors where the curb lane could carry more total passengers in bus-only mode, we further recommend restricting the lane to bus-only travel during peak hours.
- **Supporting evidence:** When the City of Los Angeles implemented and actively enforced peak-hour parking restrictions on Ventura Boulevard, average bus-travel speeds increased by roughly 10 percent (Kumar, 2007). Note that the curb lane was *not* restricted for bus-only use, so the travel speed was likely comparable for buses and automobiles.
- **Implementation obstacles:** Businesses may object that curb-parking restrictions will reduce parking capacity for their patrons, while neighboring communities may be concerned that more vehicles will need to park on the surrounding residential

streets. Applying this strategy systematically on all large boulevards throughout the region will reduce perceptions that certain businesses or neighborhoods are being treated unfairly. Another option for overcoming opposition may be to install parking meters in surrounding residential neighborhoods for visitor use under the condition that resulting revenues would be allocated to public improvements for the benefit of local residents (repairing sidewalks, burying utility lines, creating pocket parks, and the like). This could create enthusiasm among surrounding neighborhoods for the idea of allowing visitors to pay for the privilege of parking on their streets, yielding a win-win situation.

- **Initial implementation steps:** The first step will be to identify all congested major arterial thoroughfares that allow curbside parking during peak hours. At the same time, corridors with significant bus service should be evaluated for the potential to create bus-only lanes.
- **Follow-on implementation steps:** The next step will be to implement curbside-parking restrictions systematically, creating bus-only lanes in cases in which bus-only operation would facilitate greater total passenger throughput.

Recommendation 3: *Develop a network of paired one-way streets in high-volume travel corridors throughout the region.*

- **Motivation:** Converting streets from two-way to one-way operation will increase road capacity, as the median strip will no longer be required. It will also reduce delays by enabling progressive signal timing in the direction of travel and making it easier and faster to make left turns. We also recommend the development of bus-only lanes and bicycle lanes on the system of one-way streets. Though currently prevalent in downtown Los Angeles, one-way street alignments are little used elsewhere in the county.
- **Supporting evidence:** Converting two-way streets to one-way operation can increase the effective vehicle capacity by as much as 50 percent, increase traffic speeds by about 20 percent, reduce the number of intersection stops by 60 percent or more, reduce total

intersection delays by almost 50 percent, and reduce trip times by 22 to 33 percent (Cunneen and O'Toole, 2005; Stemley, 1998; TTI, 2001).

- **Implementation obstacles:** Local businesses may prefer two-way streets with slower-moving traffic so that potential customers will not speed past a store without seeing it. One-way-street proposals are often combined with curb-parking restrictions, and local businesses may oppose this as well. Owners of surrounding homes may fear more cut-through traffic when vehicles need to backtrack, and they may also be concerned that higher travel speeds will diminish the pedestrian environment and introduce safety risks. While our review of the evidence suggests that one-way streets tend to be safer than two-way streets, evidence on increased neighborhood cut-through traffic is less certain.
- **Initial implementation steps:** The first recommended step is to implement paired one-way streets on Pico and Olympic with the provision that a lane be dedicated to bus-only service during peak hours (see the plan by Rifkin, 2007). The City of Los Angeles is currently pursuing a modified version of this plan under which Pico and Olympic would remain two-way streets but the signal timing would be modified to promote faster traffic flow in a particular direction. Over time, the number of lanes allocated to traffic in the peak direction might then be extended, thus approximating one-way operation in an incremental fashion (Bernstein, 2008). Though this staged approach is reasonable, we recommend that the implementation of one-way alignments on Pico and Olympic occur in a single step to examine how this concept works in practice and determine whether it is appropriate to pursue additional one-way conversions elsewhere in the region.
- **Follow-on implementation steps:** While implementing one-way streets (with bus-only lanes) on Pico and Olympic, city planners can also examine other corridors in which paired one-way streets could offer similar opportunities. Given the density of traffic on the Westside (see Figure 3.9 in Chapter Three), this should be an area of initial focus. Assuming that the Pico/Olympic project proves successful, the implementation of other paired one-

way streets can then proceed. Note that, in many cases, it may be appropriate to extend one-way street alignments across city boundaries.

Recommendation 4: *Bolster outreach efforts to promote voluntary TDM—including ride-sharing, telecommuting, and flexible work schedules—at businesses and other large organizations throughout the county.*

- **Motivation:** In the context of our integrated policy framework for Los Angeles, the implementation of pricing strategies will require improved alternatives to driving alone during peak hours. The three strategies included in this recommendation (ride-sharing, telecommuting, and flexible work schedules—e.g., four 10-hour days per week), all present viable options for either avoiding peak-hour driving or not driving at all. Current media reports suggest that, with the recent run-up in fuel prices—which should have a similar effect on driving behavior to that of pricing strategies—many auto commuters are already seeking other options to save on their motor-fuel bills. Our recommendation is that a regional agency, such as Metro,⁴ devote greater funding to provide outreach to assist employers in developing voluntary TDM programs to create additional commuting options for their employees. We also recommend expanded support for related programs, such as dynamic ride-matching.
- **Supporting evidence:** The integrated ride-sharing program in Washington, D.C., reportedly contributes to a reduction of 5,500 trips and 146,000 VMT per day (LDA Consulting, 2006). Data from the L.A. ecommute pilot program indicated that participating telecommuters worked from home an average of one to two days per week, saving an average round-trip commute distance of 67 miles (Walls and Nelson, 2004). A study by Picado (2000) found that roughly 20 percent of surveyed employees with flexible work hours choose to shift their schedules in order to reduce

⁴ SCAG or AQMD might also pursue this recommendation.

the time spent commuting. Such statistics represent, in our view, modest but positive results. With the recent surge in fuel prices, however, and with the potential implementation of pricing strategies in the future, these types of programs may become much more successful.

- **Implementation obstacles:** Our purpose in recommending enhanced promotion of ride-sharing, telecommuting, and flexible work schedules is not to manage the demand for peak-hour automotive travel (though it may help support that aim); that role is filled instead by our pricing recommendations. Rather, in the context of our integrated policy framework, these traditional TDM measures are intended to provide additional travel options to ease the effects of high fuel prices as well as to mitigate equity concerns that might arise under a regime of pricing strategies. Accordingly, our recommendation calls for voluntary rather than mandatory measures. Political obstacles are thus not likely; rather, the primary obstacle will be related to securing the necessary funding for the effort.
- **Initial implementation steps:** One of the first steps would be for Metro (or any other agency that chooses to take the lead on this) to review available research and best practices to develop a toolbox of approaches that employers can use to increase ride-sharing, telecommuting, and flexible work schedules for their employees. The potential to enhance dynamic (ad hoc) ride-sharing options—among commuters as well as other travelers—also merits further attention. A second initial step would be to secure additional funding to support outreach efforts to employers as well as to further subsidize specific TDM programs already under way (such as the CommuteSmart regional ride-matching program and Metro’s existing vanpool program).
- **Follow-on implementation steps:** Follow-on activities would consist of direct outreach and interaction with employers to provide assistance with ride-sharing, telecommuting, and flexible-schedule options for their employees.

Recommendation 5: *Develop a network of HOT lanes on freeways throughout the county and apply any net revenue to the subsidization of express bus service in the HOT lanes.*

- **Motivation:** HOT lanes provide an opportunity to pay for faster (and more reliable) travel when a driver places a high value on travel time. They also enhance a freeway's overall vehicle-throughput capacity by making use of any excess space in the HOV lanes and varying prices to preserve optimal flow conditions in the lanes. As an additional benefit, buses can also use HOT lanes, thus improving transit services in the region as well. The fact that congestion is severe on most highways in the county (see Figure 3.4 in Chapter Three) serves as motivation for developing a network of HOT lanes rather than one or two stand-alone applications.
- **Supporting evidence:** The 91 Express Lanes in Orange County consist of four priced lanes (two in each direction) running in the median between eight general-purpose lanes (four in each direction). During peak hours, travel speed in the priced lanes averages 60 to 65 mph, while speed in the adjacent free lanes averages just 15 to 20 mph. Because traffic throughput diminishes with severe congestion, the two priced lanes carry roughly the same number of vehicles as the four free lanes during peak hours—that is, each priced lane carries twice the number of vehicles as each free lane (Obenberger, 2004).
- **Implementation obstacles:** Because HOT lanes offer many benefits, and because use of the HOT lanes is optional rather than mandatory, this strategy enjoys a high degree of public support in places where it has been implemented (Sullivan, 2000; Supernak et al., 2002). In Los Angeles, however, two implementation obstacles will need to be overcome. First, some freeways do not have HOV lanes that could be converted to HOT lanes. Second, many of the existing HOV lanes are already operating at or near full capacity during peak hours, such that there would be little space to sell to SOVs. To develop a full network of HOT lanes, it will therefore be necessary to consider such options as (1) converting current general-purpose lanes to HOT lanes, (2) increasing

the minimum number of passengers (e.g., from two or more to three or more) required to qualify as an HOV in order to free up additional space in the lane, or (3) requiring that both SOVs and carpools pay the toll (note that the desire to split the toll among multiple vehicle occupants may continue to encourage the formation of carpools). Each of these actions is likely to face opposition. Enabling state legislation will also be required.

- **Initial implementation steps:** We recommend beginning with a HOT-lane demonstration project on the I-110 Harbor Transitway facility to familiarize L.A. residents with the benefits of HOT lanes. The Harbor Transitway, an 11-mile HOV and bus facility opened in 1996, is an ideal initial candidate, as it already includes two lanes flowing in each direction, which allows for smoother operation.
- **Follow-on implementation steps:** The next step will be to develop a plan to provide HOT lanes on all congested freeways in the county. This may require, as noted, the conversion of free lanes in some cases and the modification of HOV-passenger minimums in others. Because both of these are likely to be controversial, a concerted public-outreach campaign will be needed (see Chapter Seven).

Recommendation 6: *Implement variable curb-parking charges in all busy commercial and retail districts, return a share of the resulting revenue to local merchants to invest in public amenities, and use the remainder to fund municipal transportation investments.*

- **Motivation:** Varying parking charges by location and time of day to ensure that there will usually be one or two free spaces available on any block will lead to significant reductions in congestion in busy commercial and retail areas by eliminating the need for visitors to drive around searching for an available space. If implemented broadly throughout the region, net revenues would likely fall in the range of tens to hundreds of millions of dollars annually.

- **Supporting evidence:** Studies in Washington, D.C., New York, San Francisco, and London have shown that cruising for under-priced street parking accounts, on average, for about 30 percent of the traffic in retail districts, up to 74 percent in one study. In the L.A. region, a study in Westwood Village showed that cruising accounted for more than 90 percent of the traffic in peak hours. This traffic would be virtually eliminated with variable curb-parking charges. With respect to revenue, the installation of 690 meters with high hourly rates in Old Pasadena was generating a net return of \$1.2 million per year as of 2001 (Shoup, 2005).
- **Implementation obstacles:** Implementing variable curb-parking rates may require investment in new meter technology, but increased parking revenues should easily offset the initial capital cost. Retailers may also fear that higher parking charges will drive customers away. Though this proves not to be the case, returning a share of the increased parking revenue to local merchants for investment in public amenities can overcome this potential opposition, as demonstrated with the Old Pasadena parking-benefit district experience (Shoup, 2005).
- **Initial implementation steps:** Cities can pursue this action immediately. Key steps include installing the necessary metering technology and developing a city ordinance specifying that prices will be allowed to vary such that a few spaces remain vacant on each block. The legislation should also establish that local districts receive a portion of the resulting revenue for investing in public improvements. See City of Redwood City (2005) for sample legislation.

Recommendation 7: *Enforce the existing California parking cash-out law at the municipal level in cities where a significant share of employers lease parking.*

- **Motivation:** Offering workers the opportunity to receive cash instead of free parking if they rely on alternative transportation will lead to a significant reduction in the number who drive to work alone.

- **Supporting evidence:** Shoup (1997) conducted a study of eight firms in the L.A. region that implemented parking cash-out programs. Across the eight firms, the share of workers who drove to work alone dropped from 76 percent to 63 percent, the share of carpoolers increased from 14 percent to 23 percent, and the share of transit riders increased from 6 to 9 percent.
- **Implementation obstacles:** California requires that firms with more than 50 employees that lease parking for their employees offer the cash-out option, but the law is not enforced. We recommend that cities take the necessary steps to enforce the law, given the state's failure to do so. The primary challenges are likely to fall in the legal and administrative categories, but it is not anticipated that they will be difficult to overcome. Importantly, businesses are unlikely to oppose this strategy because (1) parking cash-out is viewed as a valuable employee benefit, and (2) it costs little to implement, since the law applies only to firms that lease parking and can choose to offer the cash instead of paying the lease (Shoup, 1997).
- **Initial implementation steps:** Cities can pursue this strategy immediately. The City of Santa Monica already requires parking cash-out for qualifying employers, and the City of Los Angeles is exploring a promising approach under which employers that lease parking would be required to offer parking cash-out as part of the business-permitting process.
- **Follow-on implementation steps:** Parking cash-out will lead to significant reductions in the number of employees who drive alone to work. We recommend that parking-cash-out programs be carefully monitored to quantify these effects. The resulting information can then serve as a basis for reducing off-street-parking requirements for real-estate developments where parking will be leased. Over time, as more office buildings with leased parking are developed, the number of employers able to offer parking cash-out will increase, thus expanding the benefits of the program.

Recommendation 8: *Develop and aggressively market deep-discount transit fares to employers in areas that are well served by transit.*

- **Motivation:** Deep-discount fare programs enable large organizations (such as universities or firms) to purchase transit passes for all members or employees at significant discounts. When structured properly, they lead to increased transit ridership, increased transit-operator revenues, and reduced transit-operating deficits. And from the perspective of the purchasing organization, they are often cheaper than providing additional parking or other transportation benefits. Whereas pricing strategies recommended in this book make driving more expensive, deep-discount passes reduce the cost of transit, thereby making it even more attractive by comparison. Successful deep-discount programs already exist in the L.A. region but have been applied only to a limited extent.
- **Evidence of success:** Brown, Hess, and Shoup (2001) reported that deep-discount transit fares have led to transit ridership gains of between 70 and 200 percent among members of participating organizations.
- **Implementation obstacles:** The principal obstacles are administrative and should not be difficult to overcome.
- **Initial implementation steps:** Metro and other transit providers in the county can begin efforts to develop and market deep-discount fare programs immediately.

Recommendation 9: *Expand BRT in urban areas with dedicated bus-only lanes on the arterial network, and expand express freeway service in HOT lanes.*

- **Motivation:** This recommendation will significantly improve the speed, convenience, and reliability of public transit in Los Angeles relatively inexpensively (in comparison with current estimates of \$400 million or more per mile to construct subways). The improved transit options will provide viable alternatives for those wishing to avoid the higher price of automotive travel that would result with pricing strategies. They will also benefit the many L.A. residents who already rely on the bus system for their daily travel needs. Thus, current transit users, new transit users, and those driving on less congested roads will all be better off. While the

Metro Orange Line busway in the San Fernando Valley includes 14 miles of exclusive right-of-way, Metro's Rapid bus lines share the streets with general traffic and must therefore suffer the same congested travel conditions. Metro Rapid lines include many features of the BRT concept that has taken the transit world by storm in recent years, including signal prioritization, more-frequent service, limited stops, and real-time next-bus information at stops. These features have improved BRT travel speeds by about 20 to 30 percent over conventional local bus service (Metro, 2000). Yet, in the absence of partially or fully reserved rights-of-way, service is still slow in many places; the average daytime travel speed for Rapid buses on the Wilshire corridor, for example, is just 11 mph (Jeff, 2007a).

- **Supporting evidence:** Improving the speed of transit services can translate to significant gains in ridership. When Metro Rapid service was first introduced on the Wilshire-Whittier corridor, bus speeds increased by 29 percent, leading to a 33-percent increase in ridership; on Ventura Boulevard, Metro Rapid service increased bus speeds by 23 percent, stimulating a 26-percent increase in ridership (Metro, 2000).
- **Implementation obstacles:** Allowing buses to travel in HOT lanes on the freeway network is a promising opportunity. On the arterial system, however, the primary obstacle to providing bus-only lanes is that many drivers are likely to argue that *all* vehicles should be allowed to use the lanes. Provided that a bus-only lane will facilitate greater total passenger (as opposed to vehicle) throughput in a corridor, however, reserving a lane for the exclusive use of bus transit represents the most efficient use of the capacity.
- **Initial implementation steps:** We recommend implementing bus-only lanes on Wilshire Boulevard in the curb lane during peak travel hours—an idea already being evaluated by the City of Los Angeles and Metro—as a first step in developing a regional network of dedicated bus-only lanes on the arterial system. Bus service along the Wilshire corridor currently accommodates about

100,000 boardings each weekday,⁵ while the daily volume of cars and trucks traveling on Wilshire Boulevard—depending on the specific location—varies between just under 6,000 (at Grand Avenue) and just over 100,000 (at Veteran Avenue), averaging just under 50,000.⁶ With faster travel speeds in a bus-only lane, ridership in the corridor should expand even further.

- **Follow-on implementation steps:** The next steps will be planning and implementing a network of bus-only lanes on the arterial system and add express freeway bus service as HOT lanes are implemented. A key element of the planning effort will be to monitor the effects of the initial bus-only lanes on Wilshire, examining the outcomes with respect to bus-travel speed and ridership. Based on this information, it should then be possible to examine ridership on other major arterial corridors and project how it might increase with the introduction of bus-only lanes during peak hours. In cases in which current ridership plus anticipated gains suggest that bus-only lanes will support greater total passenger throughput, the curb lane should be restricted to bus service during peak hours. Additional opportunities to create bus-only lanes may arise with the conversion of two-way streets to one-way operation.

Recommendation 10: *Develop an integrated, regionwide bicycle network, with a specific focus on dense urban areas in which bicycles can potentially serve a large share of trips.*

- **Motivation:** This recommendation falls under the category of improving alternatives to driving in Los Angeles. While cycling may not serve as a potential replacement for a long commute, it can certainly facilitate shorter trips (and cycling in combination with transit can serve longer trips). Los Angeles offers an ideal cli-

⁵ Note that this level of ridership exceeds weekday boardings on the Metro Orange Line busway (around 22,000), the Metro Blue (around 75,000), Green (around 36,000), and Gold Lines (around 18,000). Only the Metro Red Line (around 125,000) exceeds Wilshire Boulevard's weekday transit boardings (Jeff, 2007a).

⁶ According to traffic-count data provided by LADOT staff.

mate for cycling throughout much of the year, and many excellent bicycle facilities already exist. Yet the system is not clearly legible (easy to understand) to existing or potential riders, bicycle routes are not well connected at the regional level, and existing lanes often end abruptly at municipal boundaries. To make cycling a more viable mode of transportation in the region, and especially in urban areas, we recommend the development of an integrated and legible regional bicycle network, including additional clearly identifiable bike lanes and bike paths along with improved bicycling amenities—such as bicycle-storage lockers—at transit hubs. Because bicycling can be more dangerous than driving, per mile of travel (Pucher and Dijkstra, 2000), we also recommend additional expenditures on bicycle-safety training programs.

- **Supporting evidence:** In European cities with good bicycling infrastructure, biking constitutes a sizable share of all trips. In Copenhagen, for instance, 30 percent of all trips are made by bicycle (Smith and Hatch, 2006). In Davis, California, which also offers an extensive bicycle-path network, biking accounts for 17 percent of all commute trips (City of Davis, 2006). In the greater SCAG region, by comparison, biking accounts for just 0.5 percent of all commute trips, so there is ample room for improvement.
- **Implementation obstacles:** The principal obstacle to expanding the bicycle network in Los Angeles is insufficient funding combined with the relatively low prioritization given to bicycling facilities. There may be some institutional obstacles as well; bicycling improvements are typically implemented by individual cities, and not all cities in the county have been willing to devote road space to biking. To overcome concerns that bike lanes would reduce available space for automobiles on busy thoroughfares, it may be useful to consider opportunities for creating bike lanes on less heavily traveled routes.
- **Initial implementation steps:** As a starting point, we recommend allocating additional revenue to bicycling facilities and completing Metro's existing bicycle-transportation strategic plan (Metro, 2006).

- **Follow-on implementation steps:** Further opportunities to expand the bicycle network may arise with the conversion of two-way streets to one-way operation.

Contingent Strategy Recommendations

Recommendation 11: *Evaluate the costs and benefits of implementing a regional incident-management system on the arterial network.*

- **Motivation:** Traffic incidents—including crashes, vehicle breakdowns, and the like—are responsible for a very large share of urban congestion. By facilitating faster detection of, response to, and clearing of such occurrences, incident-management systems can have a dramatic effect on reducing the resulting delays. Metro and Caltrans already fund and manage the extensive Freeway Service Patrol (FSP) system, which helps to accomplish these goals. We recommend testing a similar program on the arterial network and, should it prove successful, expanding it regionally. *Note that most incident-management systems implemented to date have focused on freeway operations, and thus there are few data to indicate how effective such a program would be on the arterial system; it is for this reason that we treat this as a contingent recommendation, one requiring further evaluation.*
- **Supporting evidence:** Studies of freeway-based systems for incident management in Minnesota (MNDOT, 2004) and Maryland (Ozbay et al., 2005) indicate that FSP assistance reduces the average incident duration by well over 50 percent. In Maryland, the FSP program reduced aggregate incident-related travel delay on the freeway system by about 15.6 million vehicle hours in a single year. A study of the L.A. FSP program (Skabardonis et al., 1998) found that FSP assistance reduced the average incident response and clearing time by about 15 minutes. LADOT has reportedly experimented with an arterial-based incident-management program, but, as of this writing, the results of the evaluation were not available.

- **Implementation obstacles:** Should arterial incident management prove to be a cost-effective strategy, the primary obstacle will be securing funding for the program.
- **Initial implementation steps:** The first step, as noted, will be to evaluate the costs and benefits of an arterial incident-management system through some type of trial or demonstration project. If the LADOT trial was sufficiently comprehensive and carefully documented, it could serve this role.
- **Follow-on implementation steps:** If, based on the preliminary evaluation, arterial incident management proves to be cost-effective, the next step would be to implement an ongoing program. While individual cities could pursue this, there may be economies of scale to be achieved through regional implementation. In this case, Metro would be the likely lead agency, as Metro already manages the county's FSP program.

Recommendation 12: *Evaluate the potential for implementing cordon tolls around major activity centers in the region.*

- **Motivation:** Cordon tolls will significantly reduce traffic congestion in the charging zone and will confer additional benefits, such as fewer traffic accidents and reduced vehicle emissions. Cordon tolls will also raise hundreds of millions of dollars per year. *Yet to date, cordon tolls have been implemented only in relatively mono-centric cities with extremely well-developed transit alternatives. It is thus unclear whether cordon tolls could be equally effective in the L.A. context without creating legitimate equity concerns. We thus categorize cordon tolls as a contingent recommendation and suggest that further research be conducted prior to pursuing implementation.*
- **Supporting evidence:** When Singapore introduced its electronic road pricing program in 1998, which included a cordon-tolling element, the average daily traffic volume in the CBD decreased by 15 percent (Fabian, 2003) and average travel speeds doubled (Goh, 2002). When London introduced its cordon toll in 2003, vehicle travel in the charging zone was reduced by 15 percent, while average travel speeds increased by 21 percent (Santos and

Shaffer, 2004). Annual toll revenues (converted to U.S. dollars) for the London, Stockholm, and Singapore cordon tolls are approximately \$385 million, \$110 million, and \$55 million, respectively (ECMT, 2006).

- **Implementation obstacles:** To implement cordon tolls in Los Angeles, three obstacles will need to be overcome. First, Los Angeles is much more polycentric than other cities where this approach has been employed; as a result, it may be appropriate to consider multiple cordon-toll areas. Second, because cordon tolls (unlike HOT lanes) are required of most drivers who enter the zone, they raise concerns that the charges might disproportionately burden lower-income drivers (Santos and Shaffer, 2004). Such concerns make it necessary to provide high-quality transit service to any area subject to a cordon toll to ensure that there are viable alternatives to driving. While revenues raised by a cordon toll can help fund improved transit services over the longer term, many of the investments will need to occur before the cordon toll is implemented in order to effectively mitigate concerns. Third, the concept of cordon tolls does not enjoy a high degree of public support in Los Angeles, both because it is an unfamiliar idea and because most drivers expect that they would incur significant costs without appreciable travel-time savings. Educational outreach about the effectiveness of this approach along with efforts to build popular and political support would thus be necessary before such a program could be pursued. Choices about how to allocate the resulting revenue will be instrumental in helping build support.
- **Initial implementation steps:** Cordon congestion tolls are complex, and the first required step will be to study the potential for their application in Los Angeles (note that Metro is currently funding such a study). Interrelated issues to address in the study include where to locate the cordon boundaries, what electronic tolling technology to employ, how to structure the tolls (e.g., flat rate versus varying by time of day), how to allocate the revenues, and how the cordon toll will affect different spatial and demographic segments of society. Given the high levels of congestion on both the freeways and the arterial network between downtown

Los Angeles and the Westside (see Figures 3.4 and 3.9 in Chapter Three), we suspect that such areas as downtown Los Angeles, Century City, Santa Monica, and LAX might emerge as promising candidates for cordon tolls.

- **Follow-on implementation steps:** Should the study find that cordon tolls would be feasible and beneficial, the next steps will be to conduct outreach, develop the necessary political consensus (see Chapter Seven), and implement the recommended tolling zones. To mitigate equity concerns, fast and efficient transit options serving the charging zones will have to be established *before* cordon-toll operations commence.

Recommendation 13: *Implement local fuel-tax levies at the county level to raise transportation revenues and (to a lesser extent) reduce the demand for driving.*

- **Motivation:** Failure to raise federal and state fuel taxes in recent years to keep pace with inflation and improved fuel economy has resulted in growing transportation-funding shortfalls in Los Angeles and elsewhere. Los Angeles has in the past relied on sales-tax ballot measures to raise local transportation funds, but fuel taxes offer more-compelling benefits. With fuel taxes, the amount one pays is based (roughly) on the amount one drives, and aligning costs and benefits can be viewed as more equitable (Wachs, 2003b). Fuel taxes also act as incentive to drive less, and this can help to reduce congestion. Finally, fuel taxes encourage the purchase of more fuel-efficient vehicles, thus leading to important environmental benefits. Neither sales taxes nor other general revenue sources offer these same advantages. To promote a stabler revenue stream and prevent the erosion of revenues due to future inflation, we would further recommend that local fuel taxes be structured on a cents-per-gallon basis and indexed to increase with either the consumer price index or the construction cost index. *Note that Metro is already taking steps to place an additional 0.5-percent sales tax to fund transportation improvements on the ballot for the fall of 2008, and it is unlikely that the county would*

simultaneously pursue a sales-tax measure as well as a local fuel-tax levy. Should the sales-tax effort stall, we would then recommend the development of a local fuel-tax measure in its stead. This leads us to categorize this as a contingent recommendation.

- **Supporting evidence:** The Victoria Transportation Policy Institute (2008e) reviewed a series of studies examining how changes in fuel prices influence decisions to drive. Over the long term, the studies suggest that a 10-percent increase in fuel prices will lead to a reduction in total VMT in the range of 2.6 to 3.3 percent. California Assemblymember Mike Feuer recently introduced legislation (Assembly Bill [AB] 2558) that would allow Metro, with voter approval, to levy a fuel tax of up to 3 percent of the purchase price of gas (roughly \$0.12 to \$0.15 per gallon at current prices). This, according to evidence in the reviewed studies, would stimulate a reduction in VMT of about 1 percent over the long term while generating close to \$0.5 billion in annual transportation revenue for the county.
- **Implementation obstacles:** Enabling state legislation, such as that proposed by Assemblymember Feuer, will be required before Metro can levy local fuel taxes. (Under AB 2558, the tax would be calculated as a percentage of the sales price of gasoline rather than as a set price per gallon indexed to increase with inflation; otherwise, the measure is broadly consistent with this recommendation.) Voters would then be required to approve the tax. Note, however, that we are using the term *tax* in its generic sense. From a technical perspective, Assemblymember Feuer has, in fact, attempted to structure AB 2558 as a *user fee* rather than as a tax (Newton, 2008). A key difference is that, under California law, user fees require only 50-percent voter approval (although there are more restrictions on the allocation of the revenue), whereas taxes require a two-thirds vote. Yet despite recent evidence that voters express growing support for efforts to link transportation funding with environmental goals (Dill and Weinstein, 2007), even gaining 50-percent voter approval may prove to be politically challenging, given that (1) the economy appears to be weakening, (2) the cost of gasoline has been rising dramatically, (3) additional

taxes will be viewed as burdensome for lower-income drivers, and (4) Metro is already pursuing a sales-tax measure for the current ballot cycle.

- **Initial implementation steps:** The first step, as noted, will be to pass enabling state legislation.
- **Follow-on implementation steps:** The second step will be to gain voter approval, and this will require concerted efforts to build political support (see Chapter Seven).

Public-Sector Roles

Table 6.3 summarizes our expectation of the roles that various governmental actors would likely fulfill in implementing the strategy recommendations, given the activities over which they have jurisdiction. Note that many of the strategies could involve multiple actors. An entry of “Lead” indicates that a particular governmental entity would likely assume leadership for implementing a recommendation, while an entry of “Required” means that the entity would need to support implementation efforts. Finally, an entry of “Optional” indicates that an agency’s involvement might be helpful but not essential.

Strategies Not Recommended

That a given strategy is omitted from our list of recommendations does not indicate that we find it to be without merit. Our purpose, rather, has been to identify the strategies that appear *most* compelling in order to help prioritize efforts and investments. Yet from a cursory review of the ratings from Figure 5.1 in Chapter Five, it is not always readily apparent why we chose to recommend one strategy over another; this results from the fact that it was not just the summary ratings, but also the detailed evaluations in Appendixes B1 through B28, that influenced the selection process.

In the preceding section, we described the motivations for including the strategies that made our list of recommendations. Here, we comment briefly on the *relative* limitations of the remaining strategies that led to their omission from the set of recommendations.

- *Freeway-ramp metering:* Caltrans has already installed an extensive network of ramp meters throughout the county and is currently testing and deploying the most advanced systemwide adaptive ramp-metering (SWARM) technology along some of the region's busiest freeways (Caltrans District 7, 2007). We did not encounter evidence to suggest that Caltrans should be pursuing additional steps above and beyond its current efforts.
- *HOV lanes:* Though HOV-lane strategies offer potential benefits, HOT lanes are even more compelling. We therefore included such lanes in the recommendations and omitted HOV-lane strategies.
- *Park-and-ride lots:* Park-and-ride lots are beneficial in supporting individuals' ability to ride-share or use transit for a portion of their trips. In our view, however, it is more pressing to first bolster the demand for these modes through strategies that raise the cost (or opportunity cost) of driving alone (e.g., HOT lanes, cordon tolls, variable curb-parking rates, parking cash-out, fuel taxes) or make alternative modes more competitive (e.g., BRT improvements, deep-discount fare programs). It should then be possible to expand park-and-ride lots relatively quickly as the demand for ride-sharing and transit increases.
- *Officers at intersections:* This strategy has proven effective where implemented (Jeff, 2006b), but has relatively high ongoing operating costs. While we would not argue strongly against this strategy, we expect that the other TSM strategies recommended will provide greater return on investment over the longer term.
- *Left-turn signals:* While this strategy can also reduce delays on the arterial network, efforts to improve left-turn capabilities appear to be ongoing in many cities (see, for example, L.A. Office of the Mayor, 2007a, 2007c). Another important factor that emerged in our review of the strategy is the inherent trade-off between safety and efficiency that arises when selecting the signal-timing protocol (i.e., protected versus permissive left-turn signal phasing; see Asante, Ardekani, and Williams, 1993, and Benioff and Rorabough, 1980). It thus appears reasonable for efforts to upgrade and improve left-turn signals to proceed at the current

Table 6.3
Public-Sector Implementation Roles

Recommended Strategies	State Legislature	Caltrans	Metro as RTPA	LACDPW	Cities (DOTs)	Transit Operators
Primary recommendations						
Signal timing and control			Lead	Required	Required	
Curb-parking restrictions					Lead	
One-way streets			Optional		Lead	
Voluntary TDM			Lead		Optional	
HOT lanes	Required	Required	Lead		Optional	
Variable curb-parking rates					Lead	
Parking cash-out					Lead	
Deep-discount transit passes						Lead
BRT with bus-only lanes					Required	Lead
Regional bicycle network			Lead		Required	

Table 6.3—Continued

Recommended Strategies	State Legislature	Caltrans	Metro as RTPA	LACDPW	Cities (DOTs)	Transit Operators
Secondary recommendations						
Arterial incident management			Lead		Optional	
Cordon congestion tolls	Required	Required	Required		Lead	Required
Local fuel taxes	Required		Lead			

NOTE: DOT = department of transportation. LACDPW = Los Angeles County Department of Public Works. Metro as RTPA refers to Metro’s broad planning function—that is, Metro as the regional transportation planning authority (RTPA) for L.A. County (see Appendix B28 for further details). Metro’s additional role as the region’s largest transit provider is captured in the “Transit Operators” column.

pace, with careful analysis of the safety and efficiency trade-offs on a case-by-case basis.

- *Rush-hour construction bans:* This strategy can also help to reduce traffic congestion, and in fact has already been instituted in the City of Los Angeles (L.A. Office of the Mayor, undated). We would support efforts to implement this strategy in cities where it is not yet in place, but we judge the other TSM recommendations to offer even greater benefits.
- *Car-sharing:* This strategy offers numerous benefits, and efforts to expand car-sharing are certainly merited. Unfortunately, the current market penetration of car-sharing in Los Angeles (roughly 2,000 members in a population with millions of drivers) is so modest that it seems improbable that car-sharing would have a significant impact at the regional scale in reducing automotive demand or expanding transportation options in the short time frame considered by this study.
- *Traveler-information systems:* Metro is already actively developing this technology under several programs, including the Regional Integration of Intelligent Transportation Systems (RIITS), the regional 511 system, and the MyTrip real-time trip planner. It is not clear that additional investments above and beyond these ongoing efforts would provide much benefit at the margin.
- *Mandatory TDM programs:* Under this strategy, employers or building owners would be required to institute TDM programs to achieve specified trip-reduction goals. We have instead recommended that pricing strategies (e.g., HOT lanes, cordon congestion tolls, variable curb-parking rates, parking cash-out, fuel taxes) be implemented to reduce peak-hour driving. Pricing strategies apply to all drivers (not just workers), are more effective in managing automotive demand over the longer term (Downs, 2004), and raise needed transportation revenue at the same time. Moreover, mandatory TDM programs are currently forbidden in California by state law; thus, the implementation obstacles would be fairly high in any event. Note that we do recommend the *voluntary* promotion of TDM measures among employers, but as a means of providing additional commute options for those who wish to

avoid the higher cost of driving alone rather than as a principal strategy for reducing the demand for driving.

- *Driving restrictions:* The typical implementation of this strategy, which uses license-plate numbers as a basis for restricting travel on certain days, has proven largely ineffective where implemented (NYC Traffic Congestion Mitigation Commission et al., 2007). While it may reduce traffic in the short term, the benefits are not lasting. Many households simply purchase more (often older and more polluting) vehicles; with additional cars (and license plates) from which to choose, they can then circumvent the restrictions. This undermines any congestion reductions and may adversely affect air quality as well. A license-plate-rationing scheme also exacerbates equity concerns; because lower-income households are less able to afford additional vehicles, they will tend to shoulder the brunt of the restrictions. Even if an alternative implementation scheme could be devised that would not lead to the purchase of more vehicles (for example, a restriction scheme based on some type of allocated permits as opposed to license plates), triple convergence would still undermine the program's longer-term effectiveness. On any given day, while some portion of the population would be not allowed to drive, the remaining population would likely be encouraged to drive *more* in response to improved traffic conditions. Over time, this would erase any congestion-reduction benefits resulting from the program.
- *Variable transit fares:* This strategy better aligns the cost of providing a transit trip with the fare charged for that trip. Over time, this should help transit operators improve the ratio of capital and operating expenses to fare-box recovery, which may, in turn, facilitate the ability to invest in needed service improvements. In the near term, however, variable transit fares would result in raising the cost of transit during the peak hours. This could, in turn, stimulate some peak-hour transit users to switch back to the automobile, working counter to the goal of reducing congestion.
- *Bus-route reconfiguration:* Metro, by far the dominant transit provider in the region, is already in the process of reconfiguring its bus-service offerings. Operators of smaller transit facilities might

also benefit through the pursuit of such an option, but, given their comparatively limited size, the regional effects would be modest.

- *Pedestrian strategies:* Pedestrian strategies can lead to a range of benefits, including more-vibrant neighborhoods and opportunities for increased physical activity among the population. In the context of our integrated policy framework, however, the primary motivation for bolstering alternative transportation modes is to provide viable options for those who wish to reduce their reliance on the automobile so as to avoid the higher cost of peak-hour driving that would result from pricing strategies. Walking can substitute for only a relatively small share of automotive trips, though, and an even smaller share of total trip-miles. Despite the benefits of efforts to improve pedestrian infrastructure, we therefore judged the strategy as playing a lesser role in the context of reducing traffic congestion.

Summary

The goal of this chapter has been to develop a set of specific short-term strategies for reducing congestion and promoting additional transportation options in Los Angeles. We began by setting forth our selection methodology, which involved two stages. First, by synthesizing several key findings and observations from earlier chapters, we could develop a guiding framework of broad, integrated policy aims that would appear to offer the greatest prospects in the L.A. context. Key elements of this framework include the following:

- relying on pricing to manage peak-hour automotive demand and raise transportation revenue
- significantly improving transit and other alternative modes
- continuing to improve the efficiency of the road network but with a shift in emphasis from moving vehicles to moving people.

With the framework in place, the second stage of the analysis was to consider which of the available options, alone or in combination,

could best support the integrated policy goals. This process, of necessity qualitative and interpretive, was informed by the high-level strategy ratings presented in Figure 5.1 in Chapter Five as well as the more detailed strategy evaluations contained in Appendixes B1 through B28. Based on this analysis, we arrived at a total of 13 recommendations. For 10 of these, described as our primary recommendations, the benefits appear to easily exceed the costs, and planning and implementation efforts can proceed without delay. The remaining three, described as contingent recommendations, also appear promising but either require further research or depend on the outcome of other events already under way.

Our study did not involve formal modeling of the transportation network, nor did we evaluate project-level implementation details. It would thus be difficult to forecast with any precision the short- or longer-term effects of implementing our 13 recommendations. If the strategies perform in Los Angeles as they have elsewhere, though, their combined effects would likely be dramatic, leading to greater travel speed and fewer delays the road network, more convenient and attractive alternatives to driving, and increased transportation revenue for needed investments. Here, we highlight the benefits that would likely result from some of our primary and secondary recommendations across these dimensions, assuming that they perform in Los Angeles as they have elsewhere.

Increasing Travel Speed and Reducing Delays on the Road Network

- Signal timing and control investments, in areas where the current technology is lacking or deficient, can increase travel speeds by 10 to 22 percent and reduce travel times by 8 to 17 percent on the arterial network (LADOT, undated[b]; MITRE Corporation, FHWA, and USDOT, 1996).
- Peak-hour curb-parking restrictions with active enforcement can improve arterial travel speed by around 10 percent (Kumar, 2007).
- Paired one-way street conversions can increase travel speed by about 20 percent and reduce travel time by 20 to 30 percent

(Cunneen and O'Toole, 2005; Rifkin, 2007; Stemley, 1998; TTI, 2001).

- HOT lanes can maintain free-flowing travel speeds (60 to 65 mph) during peak travel hours while carrying up to twice the volume as congested general-purpose lanes (Obenberger, 2004).
- Cordon tolls can reduce traffic volume in the charging zone by about 15 percent, increasing average travel speeds by up to 100 percent (Fabian, 2003; Goh, 2002; Santos and Shaffer, 2004).
- Variable curb-parking rates can reduce traffic volumes in busy commercial and retail districts by about 30 percent on average, and by up to 90 percent in at least one example (Shoup, 1997).

Making Alternative Transportation More Attractive and Convenient

- Parking cash-out can provide sufficient financial incentive for about 15 percent of employees to shift from driving to alternative modes (Shoup, 1997).
- Deep-discount transit fares can lead to transit ridership gains of up to 200 percent among members of participating organizations (Brown, Hess, and Shoup, 2001).
- BRT featuring bus-only lanes can result in much faster transit service at relatively low cost (Levinson et al., 2003); evidence from the Metro Rapid system demonstrates that reductions in travel time stimulate comparable increases in ridership (Metro, 2000).

Raising Needed Transportation Revenue

- HOT lanes can raise sufficient revenue to subsidize express bus operations in the corridor (Obenberger, 2004; Poole and Orski, 2000; SANDAG, 2007).
- Cordon tolls can generate tens to hundreds of millions of dollars in annual net revenue (ECMT, 2006).
- Variable curb-parking rates can raise well over \$1 million in annual net revenue in a single urban retail district (Shoup, 2005). Implemented throughout the region, the strategy would likely

raise tens or even hundreds of millions of dollars for municipalities in the region.

- A local fuel tax on the order of \$0.12 to \$0.15 per gallon in L.A. County would generate around \$0.5 billion in annual revenue (“Feuer Introduces Package of Transportation Bills to Raise Revenue for Local Projects,” 2008).

While many of our strategy recommendations are tailored especially for dense urban areas, others promise to be equally effective in urban or suburban settings. Table 6.4 provides a summary of the types of facilities (arterials versus freeways) and areas (suburban, urban, or commercial center) in which we would expect the effects of each of the strategy recommendations to be most pronounced.

Key Dependencies and Interactions

In closing, we would like to reiterate two crucial observations to keep in mind when considering the set of recommendations offered in this chapter. First, as indicated in the summary of benefits, both TSM and pricing strategies will help to reduce delays and improve travel speeds. Given the shorter-term effects of triple convergence, however, and the longer-term effects of general increases in the demand for automotive travel, the congestion-reduction benefits of TSM strategies are, in the end, likely to be short-lived. If Los Angeles hopes to achieve reductions in traffic congestion that are sustainable over the longer term, it is essential that the set of adopted policies include pricing strategies. Of the many strategies considered in this book, only pricing options are resistant to the erosive effects of triple convergence (Downs, 2004); that is, pricing represents the *only* approach to reducing traffic congestion that does not simultaneously induce additional peak-hour driving in response to its success. And provided that prices are allowed to rise as needed as a function of demand, pricing will also remain effective in the face of longer-term growth in the demand for automotive travel.

Second, though many of the strategies we have recommended would be highly effective if implemented on their own, there are many ways in which the recommendations, taken together, either complement or depend on one another. Stated another way, the whole of the

Table 6.4
Scope of Effects

Recommended Strategies	Arterials	Freeways	Suburban	Urban	Commercial Center
Primary recommendations					
Signal timing and control	•		•	•	•
Curb-parking restrictions	•			•	•
One-way streets	•		•	•	•
Voluntary TDM	•	•	•	•	•
HOT lanes		•	•	•	•
Variable curb-parking rates	•				•
Parking cash-out	•	•		•	•
Deep-discount transit passes	•	•		•	•
BRT with bus-only lanes	•	•		•	•
Regional bicycle network	•			•	
Contingent recommendations					
Arterial incident management	•		•	•	•
Cordon congestion tolls	•	•			•
Local fuel taxes	•	•	•	•	•

recommendations can be considered greater than the sum of the parts. While it may not prove possible to implement all of the strategies recommended here, Los Angeles would benefit greatly by implementing as many as possible as part of a coordinated and comprehensive effort. For three issues, the complementarities and interdependencies among the 13 primary and secondary recommendations appear to be especially critical.

- *Funding:* Many of the recommended strategies—but especially signal timing and control, extensive one-way-street conversions, arterial incident management, and BRT expansion—will require significant additional revenue. Cordon congestion tolls, variable curbside parking rates, and local fuel taxes all offer the potential to raise significant county or municipal transportation revenues to help in this regard. If none of these three strategies is implemented, and if Metro is unsuccessful in its efforts to pass an additional sales-tax measure, there will be insufficient funding to implement many of the more expensive strategies listed. Note that HOT lanes and deep-discount transit-fare programs may also generate net revenue but not at the level to support expensive TSM and transit strategies.
- *Ability to pay:* Cordon tolls—and, to a lesser extent, HOT lanes, variable curbside parking rates, and local fuel taxes—are likely to raise fairness concerns about the ability of lower-income drivers to afford the resulting charges. To mitigate these concerns, it will be essential to improve nonautomotive travel alternatives in the region through such strategies as voluntary employer TDM programs, deep-discount transit fares, and enhanced BRT service featuring bus-only lanes on the arterial network and express bus service in HOT lanes on the freeways.
- *Competition for road space:* One of the most promising short-term strategies for improving the speed and convenience of transit in Los Angeles is the creation of bus-only lanes in transit-rich arterial corridors, such as Wilshire Boulevard. Yet if those corridors are already congested, drivers are likely to object strenuously to the allocation of an existing lane to bus-only service, even if such

treatment would facilitate greater overall passenger (as opposed to vehicle) throughput. Peak-hour curbside-parking restrictions and one-way-street conversions are both valuable in this context because they create *additional* lane capacity—that is, capacity not already claimed for general purpose traffic. As a result, it may be easier, politically, to create bus-only lanes in tandem with curbside-parking restrictions or one-way street alignments than it would be to create bus-only lanes without these other changes.

Despite their promised benefits, implementing the recommendations we have outlined will not be easy, as many are likely to face political opposition from specific stakeholder groups or from the general public. We therefore discuss strategies for successful consensus-building in the complex political decisionmaking environment of Los Angeles in the next chapter.

Consensus-Building Recommendations

In the previous chapter, we outlined recommendations for reducing congestion and improving alternative transportation options in Los Angeles. Many of the strategies were selected in order to mitigate potential concerns that might arise with other strategies. Providing faster transit service, for instance, will help to offset the equity concerns associated with certain forms of pricing.

Even with complementary measures in place, many of the strategy recommendations are likely to face specific stakeholder concerns or general political resistance. The application of cordon tolls is perhaps the most controversial, but others—such as the conversion of general-purpose freeway lanes to HOT lanes, one-way street alignments, curb-parking prohibitions, and the dedication of bus-only lanes on arterials—will no doubt lead to spirited debate as well. For this reason, we consider strategies for consensus-building in this chapter.

We begin this chapter with a brief overview of the complexity of transportation decisionmaking in Los Angeles, mentioning many of the relevant governmental agencies and stakeholder groups that influence transportation policy and planning. We next review relevant findings from the planning and political-science literatures that suggest helpful strategies for overcoming obstacles and galvanizing public support in a political environment characterized by numerous stakeholders with diverse and often competing agendas. Based on this review, we distill several general principles for successful collective action in the context of transportation policy and planning:

- Build strong and persistent leadership.

- Maintain effective communication among agencies and stakeholders.
- Develop sufficient agreement on the problem.
- Provide credible underlying research and analysis.
- Ensure equitable allocation of costs and benefits.
- Cultivate motivated supporters.
- Ensure consistent enforcement of agreed-on rules.

Drawing on these general principles, and considering the current political context in Los Angeles along with the specific recommendations proposed in this book, we next outline several concrete steps for helping to build consensus around strategies to reduce congestion and improve transportation alternatives in Los Angeles in the near term.

The Complexity of Transportation Decisionmaking in Los Angeles

The political context for transportation decisionmaking in Los Angeles is extremely complex, encompassing numerous public agencies at different levels of government with authority over different aspects of transportation policy and planning along with a multitude of stakeholder groups—often with competing issues and agendas—able to exert some level of influence over the decisionmaking process.

Public-Sector Actors

Table 7.1 lists many of the public-sector entities involved in transportation decisionmaking in Los Angeles, organized by level of government. Appendix C describes in greater detail the roles and responsibilities of these different actors.

Given the sheer number of public actors, the potential for institutional obstacles related to the interactions among multiple agencies at different levels of governance is readily apparent. Different government actors also have different goals and mandates, and this can create additional institutional barriers.

Table 7.1
Government Actors Involved in Transportation Decisionmaking in Los Angeles

Level of Government	Agency
Federal	U.S. Department of Transportation (USDOT) FHWA Federal Transit Administration (FTA) U.S. Environmental Protection Agency (EPA)
State	California legislature Business, Transportation and Housing Agency (BTHA) Caltrans California Department of Motor Vehicles (DMV) California Transportation Commission (CTC) California Air Resources Board (ARB) California Environmental Protection Agency (Cal/EPA)
Regional (intercounty)	SCAG AQMD
Regional (county)	L.A. County Metro
Regional (intracounty)	Councils of government (COGs) in L.A. County San Gabriel Valley Council of Governments (SGVCOG) Gateway Cities Council of Government (GCCOG) South Bay Cities Council of Governments (SBCCOG) Westside Cities Council of Governments (WCCOG) Alameda Corridor Transportation Authority (ACTA)
Local (city and subcity)	Cities (88 in L.A. County) Neighborhood councils (86 certified, 10 forming in the city of Los Angeles) Other transit agencies (24 in the greater metropolitan area)

Nongovernmental Stakeholder Groups

In addition to government actors with official authority over transportation decisions, numerous stakeholder groups can influence the decisionmaking process. We have not tried to enumerate the full list of relevant stakeholders in Los Angeles; rather, we discuss the types of issues around which stakeholder groups are likely to organize and the levels of governance at which they seek to exert their influence, citing specific groups to illustrate these general categories. We also consider the most common mechanisms through which stakeholder groups influence the decisionmaking process.

Stakeholders may organize by location or jurisdiction (homeowners' associations, for example), but they are also apt to assemble based on shared interests in such issues as mobility, economic development, the environment, and equity for lower-income or other underrepresented groups (and, in many cases, stakeholder groups embrace multiple goals). The Automobile Club of Southern California (Auto Club) and the Mobility 21 Coalition are two examples of stakeholder groups with a primary interest in mobility. The L.A. Area Chamber of Commerce and the L.A. County Economic Development Corporation are concerned primarily with economic issues, while the Natural Resources Defense Council (NRDC) focuses on environmental concerns. The Bus Riders Union (BRU) works to foster the goals of mobility (primarily bus transit) and social justice. In certain cases, stakeholder groups may form to either promote or lobby against specific projects. Friends 4 Expo Transit, a group that has worked to develop grassroots support for the Exposition Light Rail Transit Line (Expo Line) project, is an example in this category.

Stakeholder groups can also be characterized based on the level of governance at which they seek to influence policy and planning decisions, although many groups work simultaneously at multiple levels. The Auto Club and NRDC are both involved in state and national policy debates, for instance, while BRU and Friends 4 Expo Transit have exerted their influence to a greater degree on regional and local decisions. Homeowners' associations typically focus exclusively on local planning decisions.

Finally, stakeholder groups have various means at their disposal to influence policy and planning outcomes. Stakeholders can engage in the political process through at least four broad avenues:

- *Lobbying and financial influence:* One of the key ways in which stakeholders can influence policy is by lobbying elected officials, expressing their positions on pending legislation. They may also donate to the campaigns of leaders whom they feel will support their causes. By the same token, they can withhold financial support when elected officials take actions that they oppose. While campaign-contribution limits are intended to prevent any single

individual from wielding too much influence over elected officials, a stakeholder group can still wield considerable financial power when a large share of its members decide to support a particular candidate.

- *Citizen action*: Stakeholders can also employ information and activism to influence policy outcomes. For example, parties can petition, boycott, or use the media to call attention to the practices of organizations (businesses or governments) with which they disagree. In this manner, small but vocal stakeholder groups can affect major decisions of interest, and even significant policy changes can begin at the grassroots level.¹
- *Direct democracy*: Another option is the ballot box, through which groups can pursue initiatives (which create laws), referenda (which can revoke laws), and recalls (which depose elected officials). Stakeholders can play a role both in gathering the necessary signatures to place a measure on a ballot and in developing support for the measure among the general public prior to an election.
- *Legal recourse*: Finally, numerous federal and state environmental and civil-rights laws provide opportunities for stakeholder groups to challenge planning or policy decisions. Examples of relevant federal statutes include the National Environmental Policy Act (P.L. 91-190) (NEPA), the Clean Air Act (P.L. 88-206) (CAA), the Clean Water Act (62 Stat. 1155) (CWA), the Endangered Species Act (P.L. 93-205) (ESA) and the Civil Rights Act (P.L. 88-352) (CRA). There are many comparable statutes at the state level, including the California Environmental Quality Act (CEQA) and the California Endangered Species Act (CESA). Under these and similar statutes, citizens are empowered to review and comment on agency plans and decisions before those plans are implemented. If public comments are not adequately addressed, or if an agency's action has violated or would violate certain statutes,

¹ Giuliano and Hanson (2004) noted that citizen action was partly responsible for landmark changes in transportation policy reflected in the Intermodal Surface Transportation Efficiency Act (P.L. 102-240) (ISTEA) and that local efforts related to climate change may become an important driver of federal transportation policy in the future.

stakeholders have grounds for a lawsuit to prevent further action. This form of legal recourse, and the threat thereof, has proven a potent tool for stakeholder activism.²

Implications for Transportation Decisionmaking in Los Angeles

Taking stock of the dizzying array of agencies and stakeholder groups active in Los Angeles, the important observation is that each has at least some influence over transportation decisionmaking in the region. While the structural relationship among agencies may appear hierarchical, the authority over decisions is often shared among various agencies and stakeholder groups. Transportation planning does not observe a simple model amenable to top-down policy actions. In fact, action is often driven from below by actors who have no formal decisionmaking authority but are nonetheless empowered by environmental and civil-rights laws and other tools afforded by a deliberative democracy, and citizen-action groups continue to demonstrate their influence in federal, state, and local legislation as well as in court. Successful transportation policy and planning in Los Angeles will thus require successful consensus-building, as cooperation among multiple actors is invariably required and individual stakeholders have a variety of mechanisms through which they can try to defeat any plan or project they dislike.

Theoretical Insights on Consensus-Building

The tangled mass of interests, values, fragmented authority, and empowered stakeholders is not unique to Los Angeles, nor is the need for building consensus among public-sector agencies and stakeholder groups unique to transportation planning. Indeed, these issues have been of central interest to political scientists and planning theorists

² NRDC, for example, has frequently and successfully challenged numerous agency decisions for violation of the CAA, the CWA, and other environmental laws (NRDC, undated). In a recent case, NRDC and BRU filed a lawsuit against Metro in June 2007 for violating CEQA by approving bus-fare increases without considering the environmental impacts—such as increased air pollution, global warming, and traffic congestion—of this decision.

for decades. We thus found it helpful to examine the body of research in political and planning theory, and this review yielded several key insights that may help to foster more effective transportation decision-making in Los Angeles.

In this section, we briefly highlight the principal findings from our review of the relevant literature (Appendix D provides a detailed discussion of our review). The first observation is that congestion represents a classic “tragedy of the commons” problem (Hardin, 1968), under which unrestricted access to a shared but finite resource (the road network, in this case) inevitably leads to overuse of that resource (severe congestion). Hardin demonstrated that such problems can be solved only by enclosing the commons (rationing access to the resource) through a set of rules involving “mutual coercion, mutually agreed upon” (Hardin, 1968, p. 1247).

Developing the necessary mutual agreement requires efforts to foster collective action, and this is difficult in an open and increasingly deliberative democratic society characterized by a broad range of often-competing interests and values. The need for collective action helps explain the decline of the rational-comprehensive model of planning, an approach often applied to transportation decisions in earlier decades. Rational-comprehensive planning assumes that a set of experts can, through a process of logical and objective analysis, arrive at an optimal solution that best serves society as a whole (Lindblom, 1959). Failure to accommodate the diverse views of multiple stakeholders in the process, however, typically undermines the conditions required for collective action. Thus, plans developed through the rational-comprehensive process, regardless of their elegance, often fail at the point of implementation because they have not achieved sufficient buy-in from the public as a whole (Black, 1990).

More recent research on policy implementation—grounded in systems theory, principles of organization behavior, individual strategizing theory, and communicative action—leads us to the “advocacy coalition framework” (ACF) (Sabatier and Jenkins-Smith, 1988; Sabatier and Weible, 2007) and “planning through consensus building” (Innes, 1996). These two theories explicitly address the need for collective action and thus suggest means for successful consensus-building.

Based on our review of these frameworks, as well as the lessons offered in other studies in the literature of transportation decisionmaking, it becomes possible to enumerate the following guidelines for fostering successful collective action:

- Build strong and persistent leadership.
- Maintain effective communication among agencies and stakeholders.
- Develop sufficient agreement on the problem.
- Provide credible underlying research and analysis.
- Ensure equitable allocation of costs and benefits.
- Cultivate motivated supporters.
- Ensure consistent enforcement of agreed-on rules.

Recommendations to Foster Consensus-Building in Los Angeles

We now offer more-concrete recommendations for successful collective action for transportation policy and planning in Los Angeles. These are based on the general principles just outlined and are also informed by the political context in Los Angeles and the specific congestion-reduction and revenue strategies recommended in this book.

Before enumerating our recommendations, however, we first discuss the key issue of leadership—that is, the question of who might take on the role of helping to build political support for the transportation strategy recommendations developed in this book. The essential leadership role can, in theory, be fulfilled either by public officials or by community groups. We recommend the latter. There are examples of elected or appointed individuals who have demonstrated tremendous leadership in the pursuit of innovative and controversial transportation programs.³ That said, public officials in Los Angeles (and

³ Mayor Ken Livingstone of London, for example, convinced the public that a cordon congestion toll would be the most effective option for reducing traffic in the CBD, implemented the program, subsequently raised the entry toll from £5 to £8, and was successfully reelected after the toll was implemented.

elsewhere) face a range of constraints that will tend to limit their ability to provide aggressive leadership in the longer term. First, decision-making authority in Los Angeles is fractured across numerous jurisdictions such that few individual leaders are in a position to unilaterally implement sweeping, controversial programs. Second, elected leaders must maintain broad popularity in order to be reelected; they will thus be disinclined to pursue controversial programs absent strong support. Third, many elected officials face term limits, and this constrains the longevity of their leadership and initiatives.⁴ A coalition of community leaders would not face such constraints and, in fact, would be in a position to provide strong and ongoing support to elected leaders across the county to pursue a coordinated and aggressive transportation agenda.

With that in mind, we now describe the specific recommendations, which are divided into two sets. The first set offers general guidance that could be pursued by community leaders interested in forming a coalition and building support for transportation-policy reforms in Los Angeles. The second set focuses on programmatic design considerations for specific congestion-reduction or revenue strategies and may be most helpful to elected officials and agency staff members in their efforts to plan and implement policies that can attract and maintain public support (or, alternatively, defuse political opposition).

General Recommendations

Form a coalition of community representatives to fulfill the political leadership role. The concept of community leaders uniting to apply political pressure for transportation reforms in response to shared concerns about congestion has historical precedents in Los Angeles. In the 1920s, an initiative led by business interests resulted in the installa-

⁴ As an example of potential discontinuity between tenures, former Los Angeles mayor James Hahn convened the Transportation Task Force (on Congestion, Mobility and Safety) (L.A. Office of the Mayor, 2004). The committee published nearly 150 recommendations spanning engineering, education, and enforcement actions on specific projects, policies, and programs. Since Hahn's succession by Mayor Antonio Villaraigosa in 2005, the report is no longer publicly available, making it more difficult to build on prior efforts or monitor progress toward the enumerated goals. Mayor Villaraigosa's administration has, in fact, implemented many of the recommendations from the Hahn report, but this example still illustrates the potential for discontinuity.

tion of the city's first traffic signals, the regulation of on-street parking, dramatic improvements in public transit, and a plan for extending the network of major east-west boulevards and highways that exists today. Business leaders were again instrumental in supporting the expansion of the freeway network in the 1940s and 1950s and in lobbying for reinvestment in rail transit in the 1970s.

Our recommendation is similar in concept to these earlier, business-led initiatives, with one key difference. It is no longer sufficient from the perspective of political feasibility, nor appropriate with regard to equity issues, for business interests alone to represent the broader community. Rather, as discussed next, a much broader group of stakeholders must be offered the opportunity to participate in the decisionmaking process.

Include diverse stakeholders when forming the community coalition. For the leadership of the community coalition to be viewed as legitimate, it must represent the full range of affected stakeholders. The coalition should thus encompass key industry groups; racial and ethnic groups; automotive, transit, and bicycle advocates; and environmental and social-justice advocates. Forging cooperation and agreement among such groups from the outset should help to defuse many of the potential conflicts that might otherwise arise in latter stages of the planning process.

Develop agreement on the need for aggressive action to halt growth in congestion. Many of the strategy recommendations in this book are likely to face initial opposition from specific stakeholders or the general public. To gain broader support for the recommendations, it will be necessary to develop a consensus perspective that (1) congestion is a critical problem in the region and must be addressed; (2) if current trends continue into the future, congestion in the region will become much worse; (3) the less controversial strategies already employed in the region will not be effective in stemming the growth in congestion; and (4) more-aggressive strategies, including the use of pricing, will therefore be needed.

Define, broadly, the problems associated with congestion to help foster agreement on the need for action. This book provides broad support for the argument that aggressive policies will be needed

to reduce congestion in Los Angeles. Yet not all will agree that congestion by itself is such a severe problem that something must be done. Though no one enjoys sitting in traffic, many residents might feel that paying congestion tolls and paying more for parking are even less desirable. For this reason, we recommend highlighting the full range of problems exacerbated by congestion so as to build greater support for the argument that action is merited. Congestion adversely affects quality of life, detracts from the region's economic competitiveness, wastes fuel and thus leads to excess greenhouse-gas emissions, contributes to local air-quality problems for lower-income and other underrepresented communities in the vicinity of crowded freeways, and slows bus service for those who rely on transit. Reducing congestion will, in turn, confer benefits across all of these dimensions. According to our review of the relevant planning and political-science literature (see Appendix D), the accumulation of credible information supporting these points is predicted to increase the number of residents and stakeholder groups willing to support more-aggressive policy steps for reducing congestion.

Develop a compelling narrative of the benefits of action to cultivate additional support. While outlining the consequences of failure to act may be sufficient to motivate some, offering a compelling vision of the benefits that will result from the comprehensive set of recommendations may persuade even more. Myers (2007), for example, noted that an effective political champion is also an effective communicator, one who can weave together both majority and minority goals and preferences to create a “community narrative” that compels communal action. Myers further argued that this narrative's effectiveness is not necessarily bolstered by scientific analysis alone, but instead by an artful mix of future-oriented graphics, metaphors, and storytelling (see also Myers and Kitsuse, 1999).

Develop support for comprehensive programs rather than individual projects. The congestion-reduction strategy recommendations offered in this book were selected to complement or reinforce one another. For instance, cordon tolls will reduce traffic congestion in crowded urban zones, and they will also raise significant revenue for transportation investments. Transit improvements will provide viable options for those wishing to avoid the higher charges for driving during

peak hours, and they will also offer benefits to those who already rely on nonautomotive modes of travel. One-way street alignments will lead to improved travel speed and reduced intersection delays for automobiles, and they will introduce opportunities for creating bike lanes and bus-only lanes. As a package, the integrated strategy recommendations offer greater combined benefits, spread the costs more evenly, and offset many of the concerns that might apply to specific strategies in isolation.

We recognize that building support for comprehensive reform packages has proved difficult in the past; indeed, it is often necessary to first agree on modest, incremental actions to build the groundwork for further actions at a later stage.⁵ Accordingly, a reasonable approach might be to initiate a public dialogue and begin to develop familiarity and support for the idea of comprehensive reforms at the abstract level while promoting specific projects (e.g., a HOT-lane demonstration project) for initial implementation. As the public becomes more familiar with the effectiveness of the initial projects, it may then become possible to build support for more systematic reforms.

Recommendations That Apply to Specific Strategies

Apply congestion-reduction strategies systematically. Certain strategies, such as one-way-street conversions and the prohibition of curb parking, may benefit motorists and transit users who travel in the corridor but impose costs (real or perceived) on local residents and merchants. To reduce concerns that certain groups are being asked to sacrifice for the benefit of others, we recommend implementing such strategies throughout the region (following, in some cases, initial demonstration projects to help familiarize residents with the benefits offered by some of the more innovative strategies). This will diffuse the costs and spread the benefits more broadly such that specific neighborhoods and retail districts will not feel that they have been singled out for unfair treatment.

⁵ See, for example, Willson's (2003) discussion of the experience with parking-pricing reforms for the Bay Area Rapid Transit (BART) system.

Allocate pricing revenues to enlist support and mitigate equity concerns. Lack of organized support, on one hand, or spirited opposition, on the other, can prevent the implementation of pricing policies. Yet such strategies create a significant revenue stream, and the revenues can help to both build support and defuse opposition. For example, three possible allocations of the revenue resulting from cordon congestion tolls might include paying for public amenities in the charging zone, improving transit services in and around the charging zone, and partially subsidizing toll rates for lower-income motorists with demonstrated need (the tolls should not be entirely eliminated for lower-income drivers, as this would defeat the intent of using prices to manage peak-hour travel demand). Such allocations may help enroll the support (or at least reduce the opposition) of local retailers and social-justice advocates, two of the groups most likely to oppose cordon tolls. Returning a portion of revenues to local merchants for public improvements has also been demonstrated as an effective strategy to build support for variable curb-parking rates (Shoup, 2005). Suitable protections should be instituted to ensure that funds are expended only for specified purposes.

Allocate gas-tax revenues to build broad geographic support for the measure and ensure that revenues will be dedicated strictly to projects to improve mobility and reduce congestion. Local fuel taxes would likely be implemented at the county level. To build widespread support for this revenue measure, it is thus important to ensure that the benefits are broadly and fairly distributed. Echoing the importance of early stakeholder engagement, Hamideh et al. (2006) reported that local transportation ballot measures are more likely to be successful when the public has the opportunity to comment on the specific projects that it would most like to see funded. This may include transit improvements in denser urban areas and road improvements in more sparsely populated outlying areas. Strong protections should be provided against diversion of funds to nontransportation uses, and recipients should be subject to maintenance-of-effort requirements to ensure that new revenues are treated as additions to current transportation expenditures, not substitutes for them.

Provide strong enforcement for strategies that involve pricing or restrictions. Recommended strategies that require strong enforcement include cordon tolls, HOT lanes, variable curb-parking rates, curbside-parking restrictions, and bus-only lanes. For strategies requiring that motorists either pay more or change their behavior, resentment will build if there is a perception that others are able to cheat the system (Short, 2004). Strong and consistent enforcement prevents this, and the resulting citation fees can help offset the costs of enforcement.

Summary

Many of the congestion-reduction strategies recommended in this book are likely to face initial opposition from specific stakeholder groups or the general public. The goal of this chapter has been to develop political consensus-building strategies to help overcome these likely implementation challenges.

We began with a brief description of the complexity of the transportation decisionmaking environment in Los Angeles, which includes numerous agencies operating at multiple levels of governance along with a multitude of stakeholder groups representing a diverse range of often-competing issues and agendas. Two conclusions emerged: Cooperation among multiple actors will invariably be required, and individual stakeholders have a variety of legal and democratic mechanisms through which they can attempt to defeat any plan or project that they find objectionable. These findings highlight the need for successful consensus-building.

Toward that end, we next reviewed the theoretical planning and political-science literatures for insights on factors that support effective planning in the face of such political complexity (the full discussion of this review is presented in Appendix D). Our review encompassed such concepts and frameworks as the tragedy of the commons, the rational-comprehensive planning paradigm, the ACF, and planning through consensus-building. From this review, the following emerged as key factors to support successful political consensus-building:

- strong and persistent leadership
- effective communication among agencies and stakeholders
- sufficient agreement on the problem
- credible underlying research and analysis
- equitable allocation of costs and benefits
- motivated supporters
- consistent enforcement.

By interpreting these general principles in the context of the political decisionmaking environment of Los Angeles and the specific congestion-reduction and revenue strategies proposed in this book, we could develop a set of specific political consensus-building strategies for transportation policy in the region:

- Form a community coalition to provide leadership and marshal support.
- Include a broad range of stakeholders in the coalition.
- Develop agreement on the need for aggressive policy action.
- Define the congestion problem broadly to facilitate agreement.
- Develop a compelling narrative of the benefits of action.
- Support comprehensive programs rather than piecemeal projects.
- Apply strategies broadly to spread costs and benefits.
- Allocate pricing revenues to build support and offset opposition.
- Allocate gas-tax revenues to build broad geographic support.
- Strongly enforce strategies that involve pricing or restrictions.

Final Thoughts

Integrating Short-Term and Longer-Term Strategies

This book focuses on strategies for reducing traffic congestion and improving transportation alternatives that L.A.-area officials could implement and see results in the short term, which we have defined as a period of roughly five years. Yet there are many longer-term options worthy of consideration as well. Land-use strategies related to zoning, density, parking supply, and the mixing of uses, for instance, may facilitate development patterns that support greater use of public transit and other nonautomotive options, while major transit investments will also expand the array of choices available to travelers and help to reduce reliance on the automobile. And though major road expansions may be unlikely in the densest areas of Los Angeles, strategic improvements should prove useful in relieving existing bottlenecks. Though the benefits of such strategies may not be realized for some years to come, Los Angeles would do well to expedite the evaluation and implementation of appropriate land-use reforms as well to develop a revenue stream capable of supporting greater investment in needed transportation-infrastructure improvements. Otherwise, the potentially considerable benefits of these longer-term strategies in helping to reduce congestion and improve transportation options in Los Angeles will remain just that: longer term and just out of reach.

With this in mind, it is also useful to consider the manner in which the shorter-term strategies recommended in this book might interact with longer-term strategies for Los Angeles. Broadly speaking, we expect that they will prove complementary. Such strategies as local fuel taxes, cordon tolls, and parking charges, for instance, should pro-

duce significant and lasting revenue streams that can support longer-term transportation-infrastructure investments in future years. The adoption of pricing mechanisms to manage automotive demand, in turn, should increase public support for land-use reforms leading to denser land-use patterns clustered around high-capacity transit corridors and hubs.

At the same time, we would like to note that some of the recommendations in this book might be viewed as transitional. For instance, the recommendation for improving BRT in Los Angeles includes the suggestion of implementing bus-only lanes on Wilshire Boulevard, perhaps the densest transit corridor in the region. Over the longer term, it may, in fact, prove beneficial to construct a subway line extending the length of Wilshire, as Metro is currently considering. In the interim, the implementation of bus-only lanes would further boost transit ridership in the corridor; this should, in turn, reduce the level of subsidization that would eventually be needed to build and operate a subway line in the corridor (an increase in transit patrons leads to increased fare-box revenues, which, in turn, reduces the need for subsidies).

In this same vein, when considering pricing strategies to help reduce or manage the demand for peak-hour automotive travel, we included only those options that could plausibly be implemented within about five years. This led us to omit the option of networkwide road pricing enabled by in-vehicle computers equipped with Global Positioning System (GPS) devices and digital road networks. This technology, recently explored by planners and researchers in such places as Oregon and the Puget Sound region in Washington (see discussion in Sorensen and Taylor, 2006), would enable the application of road-user charges based on a range of factors encompassing distance traveled, time and location of travel, and vehicle characteristics, such as size, weight, and emissions. With this flexibility, networkwide road pricing could eventually replace many of the pricing strategies considered in this book, including HOT lanes, cordon tolls, and fuel taxes.

Yet networkwide road pricing would also represent a significant shift from current practices. Developing more modest pricing applications in the short term, such as HOT lanes or variable parking fees, may help familiarize residents with the general benefits of this approach and

lay the groundwork for subsequent implementation of more advanced forms of pricing in future years.

Transportation in an Energy- and Climate-Constrained World

Since we initiated this study in the summer of 2007, fuel prices have climbed precipitously and the economy has teetered toward recession. Contrary to our assertion that long-term trends suggest continued growth in congestion on the L.A. road network in the coming years, data from PeMS indicate that traffic delays on some local freeways have, in fact, experienced modest declines between 2007 and 2008. One would expect that the economy will, with time, recover, but it is not clear that the days of cheap oil will return anytime soon.

At the same time, growing concern with climate change and with the significant contribution to greenhouse gases that results from fossil-fuel consumption in the transport sector suggests the likelihood of future regulations that would further raise the cost of driving conventionally powered automobiles. California has already passed historic legislation to reduce greenhouse-gas emissions in the form of AB 32, though implementation details have yet to be worked out, and both the Republican and Democratic presidential candidates have expressed their support for a federal cap-and-trade program to reduce carbon emissions.¹ Under such regulations, the cost of burning oil will surely rise, and the increase will ultimately be passed along, directly or indirectly, to the consumer.

¹ Under a federal cap-and-trade program, the United States would specify an upper limit on the total level of carbon emissions that could be released each year, and this limit would gradually be reduced each year to reduce the threat of climate change. Major carbon emitters—such as electric utilities and oil refineries—would need to acquire permits to emit a certain amount of carbon each year, and these permits could be traded among firms. That is, firms able to reduce their carbon emissions at a relatively low cost could sell their excess permits to firms that would find it more expensive to reduce their carbon emissions. A cap-and-trade program would thus create a market—and a corresponding price—for carbon emissions. It is likely that firms would pass at least some of this price to end-use consumers.

While it is impossible to predict the future with certainty, these developments make it plausible that the cost of gasoline at the pump will remain high, or perhaps rise even further, in the coming years. After several decades during which population and incomes have risen and the inflation-adjusted cost of fuel has declined—resulting in the more or less steady growth in driving and congestion suggested earlier in Figures 2.1 and 3.4 (in Chapters Two and Three, respectively)—we may now be witnessing the early indications of a profound shift in the trajectory of energy markets and their influence on travel behavior. In response, auto manufacturers may begin to offer more fuel-efficient conventionally powered vehicles along with new alternatives, such as electric vehicles, plug-in hybrid vehicles, and hydrogen fuel-cell vehicles.

Yet the existing fleet of vehicles already on the road represents an enormous sunken cost for society, and a massive shift to more-efficient and environmentally benign vehicles would likely take years to unfold. If, in the interim, prices at the pump remain in the \$4 to \$5 range, we might expect that congestion would continue to ease, although it is doubtful that it would abate entirely. While still a problem, then, finding ways to reduce congestion in Los Angeles would likely move lower on the priority list of many residents. Should the price of fuel rise even higher, on the other hand, concerns over traffic congestion might well be supplanted entirely by concerns over the cost of basic mobility, especially among those living in remote suburbs and facing long daily commutes.

Given the potential for such scenarios, it is useful to reexamine the merits and limitations of the recommendations developed in this book against a possible future backdrop of high and rising fuel prices. Our book, by design, focuses on options that might be implemented in the near term, and the analysis assumes that the pattern of steady growth in travel and congestion in recent decades will continue in the coming years. But what if this assumption is mistaken? What if fuel prices continue to rise rapidly—either as a function of the global supply and demand for oil or the imposition of a regulatory framework for reducing carbon emissions—and this, in turn, triggers a lasting decline in

automotive travel? The key question is whether our recommendations would still make sense should the future unfold in this manner.

On reflection, we believe that the majority of the recommendations in this book would still be sensible to pursue even if the rising price of fuel continues to dampen the demand for automotive travel, although the relative priority among the strategies might shift to a certain degree. One of the key themes that emerge from our recommendations is the need to improve alternative transportation opportunities in the region, encompassing such options as public transit, ride-sharing, telecommuting, and cycling. In the context of the guiding policy framework developed in Chapter Six, a principal motivation for bolstering alternative modes is to enable travelers to avoid the higher charges for peak-hour driving that would result from the implementation of pricing strategies. In a future characterized by high energy prices—which would likewise raise the price of driving—travelers would still be motivated to take advantage of options other than driving alone. In short, investments in alternative transportation modes would be just as useful and might even take on a higher level of priority. Some of the alternative transportation strategies not recommended in this book—such as car-sharing, bus-route restructuring, and pedestrian strategies—might receive more attention as well.

A second theme in our recommendations is the application of strategies for using the existing road network as efficiently as possible. Here, the picture is somewhat mixed. If automotive travel diminishes in the coming years as a result of higher fuel prices, the idea of expending considerable funds in the pursuit of marginal efficiency gains on the system of highways and arterials may make less sense. One would need to ask, for example, whether the hundreds of millions of dollars that would likely be required for significant signal timing and control upgrades throughout the county might be better spent on improved transit services. On the other hand, several of our recommendations in this vein have stressed the concept of improving efficiency in terms of passenger rather than vehicle throughput. For instance, our strategy assessments favor curbside-parking restrictions and one-way street alignments not just for the expanded capacity they create, but also for opportunity to use that capacity to create bus-only lanes in transit-rich

corridors. Should the demand for transit continue to rise in response to higher fuel prices, these recommendations would still be valuable. In fact, higher fuel prices—by easing congestion and increasing the demand for fast and convenient alternatives to the auto—might well engender an unprecedented level of political support for carving out a network of bus-only lanes on the arterial network.

The final and most controversial theme in the recommendations is the use of pricing strategies to manage peak-hour automotive demand and simultaneously raise needed transportation revenue. We would argue that the pricing strategies discussed in this book still make sense to pursue even if higher fuel prices act to depress automotive travel, though the logic underlying this position is somewhat subtle. To begin with, we recognize that the already-tenuous political prospects for implementing pricing measures may become even more difficult as fuel prices rise and congestion eases. Yet unless fuel prices climb much higher still, it is unlikely that traffic congestion in Los Angeles will disappear. The spatial and temporal extent of congestion might diminish, but the busiest roads and freeways will still be subject to overcrowding during peak hours.

By managing demand and helping to reduce congestion, pricing strategies would continue to promote improved social outcomes—bolstering economic efficiency, reducing time wasted in traffic, and reducing excess fuel consumption and emissions. (In fact, road pricing strategies are often discussed as potent option that might be included in a regulatory framework intended to curb greenhouse-gas emissions.) At the same time, should increased fuel prices contribute to higher demand for transit and other options, the revenue raised through pricing measures can serve a valuable role in helping to subsidize alternative transportation improvements.

Finally, with regard to the question of political feasibility, it is important to stress that the level of charges imposed with pricing strategies, such as HOT lanes, cordon tolls, and variable curb-parking rates, is a direct function of demand (note that this argument does not hold for the strategy of local fuel taxes). When more individuals are trying to drive or park during peak hours, the price must be higher in order to prevent congested conditions. Correspondingly, when fewer indi-

viduals are competing for available road space or parking capacity, the level of the charge needed to prevent excess congestion is lower. Should higher fuel prices reduce the demand for automotive travel, the prices imposed through HOT lanes, cordon tolls, and variable curb-parking rates should fall in response (and, in fact, should congestion disappear, the charges would go to zero). In other words, *as fuel prices rise, the burden of these pricing strategies would be reduced*. If this admittedly subtle point can be clearly conveyed to decisionmakers and the population at large, it may help to at least soften resistance to the idea of introducing pricing strategies when fuel prices are already at record highs.

In short, the majority of strategies we recommend would still, in our judgment, be worth pursuing should rising fuel prices continue to dampen the growth in travel demand. Moreover, it is far from clear that recent declines in congestion delays resulting from higher fuel prices and a softening economy will persist in the long term. At some point, the economy will begin to strengthen again, and travel demand will begin to grow in response. And as individuals begin to purchase more fuel-efficient vehicles, the price of gas or diesel will have proportionately less bearing on their travel decisions. If we assume continued growth in population and the economy in Los Angeles in the coming decades, and if corresponding steps are not taken to curtail automotive demand and improve alternative transportation modes, longer-term growth in the severity of congestion remains a strong likelihood. Notwithstanding the recent reductions in traffic congestion, in our view, it is still worthwhile to initiate the process of debating and building support for the types of strategies recommended in this book.

The Debate Over Congestion-Reduction Strategies

Political debates about reducing congestion in Los Angeles have often revolved around how best to spend limited transportation dollars on transportation-capacity improvements. Should the region invest in additional rail lines or BRT service, add more left-turn lanes and signals, augment the signal timing and control system, or widen freeway bottlenecks? Such investments are often beneficial, but they offer little

prospect for stemming the growth in congestion in the region, let alone reversing it. Neither do the most commonly proposed land-use strategies offer much hope in this regard. Some people favor restricting denser urban development to prevent already-severe congestion from growing worse. Yet efforts to stem the inexorable rise in population seem destined to fail, especially when many households are willing to share increasingly crowded quarters, given the lack of affordable housing. Moreover, travel demand increases with economic growth, not just population growth. Others call for greater urban density, arguing that this will make for more vibrant urban communities, enhance the prospects for cost-effective transit investments, and result in lower per capita VMT and congestion at the regional scale. While such a strategy may indeed meet these aims, a realistic appraisal of urban infill leads to the conclusion that greater density intensifies congestion locally.

The fact that public officials and advocacy groups often constrain the debate to this limited set of strategies is understandable. Such strategies do not require that residents pay more or change their travel behavior and are thus likely to be viewed as more palatable. Strategies that involve the use of pricing to reduce peak-hour driving, in contrast, face greater potential political obstacles. Yet a key finding of this study (and many others) is that pricing strategies, collectively, represent the only legitimate option for curbing congestion in the long term and that they will be immediately effective on implementation. The real issue to debate, then, is not which combination of transit investments, road improvements, and land-use reforms will prove most effective in reducing congestion in Los Angeles. Rather, it is whether Los Angeles should implement pricing to manage the demand for peak-hour automotive travel or instead allow congestion to worsen over time. In concert with pricing, strategic transit improvements, road investments, and land-use policies will play a valuable role in reducing traffic congestion and increasing regional vibrancy. Absent pricing, and under the assumption that historical patterns persist, these strategies will, at best, reduce the rate at which congestion worsens.

The Challenges

In this book, we have cited numerous examples demonstrating the effectiveness (and revenue-generating potential) of pricing programs where they have been implemented. We have also presented theoretical arguments that pricing—by reducing the gap between the private and social costs of driving—will improve net social welfare. Even so, some will view themselves as worse off under a system of pricing, while some will oppose pricing as a matter of principle. The planning and implementation of pricing will thus be an exercise in building political consensus, and this will, in turn, require efforts to mitigate equity concerns—real or perceived—related to road pricing. For this reason, we have deliberately recommended a complementary set of strategies to reduce congestion, mitigate equity concerns related to road pricing, and distribute both costs and benefits broadly.

Ultimately, however, success or failure lies less in the realm of detailed engineering and policy analysis and more in the political arena. Based on the research in this study, our recommendations are logical. Yet this is not the first book to recommend the pricing approach. Implementing pricing policies will be far more difficult in practice than is recommending them, and the political challenges will be further compounded by the complexity of the decisionmaking environment in Los Angeles, in which cooperation among multiple agencies is often required and small but vocal opponents have ample democratic and legal options for derailing the process.

The Opportunities

Our research also demonstrates that successful collective action *is* possible—with strong and persistent leadership, in a process that includes all stakeholders from the start, and with a willingness to ensure that all concerns receive due attention. And while there may be political opposition to some of the recommendations in this book, we are also currently witnessing a confluence of circumstances that may favor aggressive and innovative transportation-policy reform.

To begin with, traffic conditions, notwithstanding recent declines in congestion delays in the past six to nine months, have deteriorated rapidly in the opening years of the 21st century (see Figure 3.8 in Chapter Three). Judging from the quantity and content of articles and editorials in the local press and traffic-related blogs, frustrations are clearly mounting. Developing a consensus agreement that something must be done may therefore be easier now than in years past. Moreover, in the articles and editorials diagnosing local traffic conditions in Los Angeles, arguments in favor of pricing seem to be appearing with greater frequency.

At the same time, concern about many of the issues influenced by congestion—the risks of climate change, the adverse health effects of poor air quality around freeways and ports, and the economic vitality of the region as a whole—also appear to be waxing. This represents an important opportunity to gain broader support for implementation of aggressive transportation-policy innovations capable of producing meaningful reductions in traffic congestion, bolstering alternative modes, promoting greater economic efficiency, and improving health and environmental outcomes.

Finally, many elected officials in Los Angeles seem to be more willing to consider pricing as an instrumental strategy for reducing congestion in the region, and the agencies under their direction have already taken important steps to lay the necessary groundwork. As of this writing, the Metro Board of Directors has voted to accept federal funding under USDOT's Urban Partnership program² to develop HOT lanes on the I-10, I-110, or I-210 freeways and augment express bus service in those corridors. Metro has also commissioned a study to examine other possible pricing applications—including both HOT lanes and cordon tolls—in the county. The City of Los Angeles, in turn, has taken preliminary steps that would allow for the enforcement of parking-cash-out laws among firms operating in the city. LADOT has also begun to install updated parking-meter technology that would allow the city to charge variable parking rates for curbside spaces. Each

² For more on the Urban Partnership program, see USDOT (undated).

of these developments is broadly consistent with the recommendations in this book.

Yet such efforts are still in the preliminary stages, and concerted political opposition may arise as the plans are further developed and become more widely publicized. To bolster the prospects that these concepts eventually reach the implementation stage, it will be extremely valuable—likely necessary—to cultivate a strong base of political support to help counterbalance any opposition that emerges. The political consensus-building recommendations presented in Chapter Seven are intended to provide guidance in this endeavor. Though the process may not be easy, we posit that the ends will justify the effort. Taking meaningful steps to reduce congestion in Los Angeles will help to improve quality of life, enhance economic competitiveness, reduce greenhouse-gas emissions, improve air quality in freeway-adjacent neighborhoods, and improve mobility for drivers and transit patrons alike.

Strategy-Rating Overview

The purpose of this study was to identify strategies capable of achieving significant reductions in traffic congestion throughout Los Angeles in the *short term*, defined as roughly five years or less. This rules out major capacity investments—such as new rail-transit lines or additional highway lanes—that take many years to finance, plan, approve, and construct. It also precludes most strategies related to land-use policy, such as modified zoning controls or off-street parking requirements. Though such policies could be implemented more quickly, it would take many years for their full effects to ripple through the built environment.

Even with major capacity investments and land-use reforms eliminated from the slate of options, there are still numerous strategies to consider, including such diverse options as improved signal synchronization, congestion pricing, employer-mandated trip-reduction programs, and enhanced transit service. To cull through the many possibilities and identify those strategies offering the greatest potential for short-term congestion relief in Los Angeles, we developed a framework for assessing the relative strengths and limitations of each. The framework is intended to be reasonably comprehensive, considering such issues and questions as the following:

- *Cost and effectiveness*: How much does the strategy cost to implement? Would the strategy, as with congestion pricing, produce

net revenues? How effective will the strategy be in reducing congestion, in both the short and long terms?

- *Other traveler benefits:* Will the strategy in question produce other travel-related benefits beyond congestion relief, such as improved mobility, accessibility, or traveler choice?
- *Other social outcomes:* How will a given strategy influence other social goals, such as health and safety, economic efficiency, the environment, and equity outcomes? If a strategy performs poorly along one or more of these dimensions, can complementary strategies mitigate the negative effects?
- *Implementation obstacles:* Are specific stakeholders, elected officials, or the public at large likely to view the strategy unfavorably? Are there institutional or interjurisdictional challenges that are likely to make successful implementation more difficult? Are there strategies for overcoming such barriers?
- *Current implementation in Los Angeles:* Has a particular strategy already been implemented in the region? If so, how well has it worked to date? Are there opportunities for improvement?

Appendixes B1 through B28 provide detailed assessments, following the framework just outlined, for each of the congestion-reduction strategies examined in this book. Here, we provide further background on how the assessments were constructed. First, we offer a broad discussion of the analysis framework, including the development of a qualitative rating system, the identification of specific criteria to consider, the sources of data used to support the assessments, and the manner in which we address uncertainty in the ratings. Second, we discuss each of the criteria included in the framework in greater detail, commenting on the relevance of each criterion and enumerating the set of ratings (for example, *neutral*, *good*, or *very good*) that could be used to describe the performance of a particular strategy with respect to the criterion. Third, we introduce several composite ratings—that is, ratings based on several related criteria—that prove useful in summarizing the overall performance of the different strategies considered.

Strategy-Assessment Framework

To characterize the strengths and limitations of these different strategies, we developed an assessment framework in which each strategy is rated across a range of criteria, including net cost/revenue implications, short- and long-term effectiveness in reducing congestion, other travel-related benefits (mobility, accessibility, and traveler choice), performance with respect to other social goals (safety, economic efficiency, equity, and environmental outcomes), potential political or institutional obstacles that may impede implementation efforts, and the current level of implementation in Los Angeles. In the next section, we provide details on each of the specific ratings incorporated in the framework. Here, we discuss several higher-level considerations that guided the overall development of the assessment framework.

Qualitative Assessments

In considering the potential advantages and disadvantages of alternative strategies for reducing congestion in Los Angeles, it would be helpful to develop specific, quantified estimates of the outcomes that would result from different options. For example, one might forecast that the implementation of a cordon congestion toll around LAX would raise \$85 million in annual revenue and reduce the number of cars entering the cordon zone during peak hours by 15 percent. Unfortunately, it has not been possible to develop such specific estimates in the context of this study. Our charge has been to assess a wide range of alternatives, and this has precluded the ability to examine any individual strategy in exhaustive detail. We have instead addressed strategy options at the policy level, considering the *likely* benefits or drawbacks that might unfold, for example, if local governments in Los Angeles chose to implement cordon congestion tolls around busy activity centers, to place greater emphasis on bicycling and pedestrian infrastructure, or to invest more money in signal synchronization on the arterial system. Such policy-level decisions would lead, in turn, to specific project proposals, and it would be necessary to perform careful analysis at the project level in order to quantify likely outcomes. With such a wide

range of policies to consider, engaging in project-level analysis exceeded the scope of our study.

In place of quantified estimates, we have instead established a set of qualitative ratings for the different criteria of interest. For example, we rate the potential of a given strategy to reduce congestion in the short term as *negligible*, *low*, *medium*, or *high*. The specific qualitative ratings available for each of the criteria, along with their interpretations, are enumerated subsequently.

Evidence Base

The ratings for each strategy, though qualitative, are still evidence-based. In our analysis of each strategy, we relied on several data sources. For ratings related to costs, revenues, effectiveness in reducing congestion, other travel benefits, other social goals, and potential implementation obstacles, we began with a thorough review of the relevant research and industry literatures. In cases in which a strategy has already been implemented in Los Angeles, we also reviewed any available reports that have examined the results of the strategy to date. To assess the current level of implementation for different strategies in Los Angeles, we interviewed knowledgeable staff at the relevant local agencies, including Caltrans District 7, LACDPW, Metro, LADOT, and transportation agencies in smaller cities in the region, such as Santa Monica and Culver City. We also reviewed numerous staff reports discussing current and future transportation initiatives.

Scope of Implementation

Such factors as the cost and effectiveness of a particular strategy depend to a significant extent on the level of implementation. For example, the cost of upgrading the signal-synchronization technology at an individual intersection is obviously much lower than the cost of upgrading hundreds of signals. In rating individual strategies according to various criteria, we have estimated such factors as costs, revenues, and effectiveness in reducing congestion under the assumption that the strategies would be implemented systematically throughout the region.

Modified Ratings

Many strategies, if implemented alone, could have negative outcomes for one or more of the rating criteria. For example, while the development of cordon congestion tolls would impose costs on all peak-period drivers, the tolls would impose greater financial hardships on lower-income drivers, leading to adverse equity effects. In many cases, however, complementary measures can help mitigate negative outcomes. Continuing with the same example, cordon congestion tolls also raise considerable revenue, and a share of this funding can be used to reduce the negative consequence for lower-income drivers. Toll revenues can be invested in better transit services, for instance, or to subsidize reduced lifeline toll rates for those drivers most in need of such support. In cases in which a reasonable mitigation option exists, we assume that the mitigation option would be implemented in concert with the primary strategy and modify the rating accordingly. With cordon congestion tolls, for instance, the initial rating on equity effects might be *very bad*. Appropriate allocation of the revenue could at least partly offset the negative effects, however, leading to a modified rating of *bad* (even with improved transit service or reduced congestion tolls, some lower-income drivers would still consider themselves worse off). In cases in which there is not an obvious opportunity to mitigate the negative consequences associated with a strategy, the rating is left unmodified.

Addressing Uncertainty

Even with a qualitative rating system, it is, at times, difficult to estimate the performance of a particular strategy with respect to one or more of the rating criteria. In certain cases, there are simply insufficient data in the research literature to assess a particular outcome. In other cases, the outcomes would depend on complementary policy decisions that are difficult to predict in advance. In still other cases, we have grouped numerous options together under a single strategy heading (as with BRT features, pedestrian strategies, and bicycle strategies), and the likely outcomes would be contingent on the specific set of options selected for implementation. Under these circumstances, we have based our ratings on what we expect would be the most likely outcomes, but we describe our ratings as *uncertain*.

Complementary and Contradictory Strategies

At the end of each strategy assessment, we also consider potential interactions with other strategies. These can be either complementary or contradictory. For example, improved bus service would be considered complementary to congestion pricing, in that it provides travelers with more appealing alternatives to driving during the peak periods. In contrast, flexible work hours could make it harder to establish effective ride-sharing programs, since potential ride-share partners might decide to come and go from work at different hours. Note that this section of the assessment, unlike the others, does not include ratings.

Individual Strategy-Assessment Criteria

For each of the strategies considered, we have developed ratings for 12 criteria, as follows:

- net cost/revenue implications
- short-term effectiveness in reducing congestion
- long-term effectiveness in reducing congestion
- mobility, accessibility, and traveler choice
- safety
- economic efficiency
- equity
- environment
- stakeholder concerns
- political obstacles
- institutional and jurisdictional obstacles
- current status in the L.A. region.

This section provides additional details for these criteria. For each, we provide a general description of the types of outcomes that the criterion is intended to represent, list the set of qualitative ratings used to assess strategies against the criterion, and offer a brief interpretation of each rating. In cases in which rating modifications are possible, we also discuss the logic for potential modifications.

Cost/Revenue Implications

Virtually all strategies entail at least some capital or operational costs. A few strategies—such as congestion pricing—also result in new revenues. The purpose of this assessment is to judge the net cost/revenue implications of a given strategy *from the public-sector perspective*. Note that certain strategies also entail costs to firms or to individual travelers, and we explicitly mention such costs where they exist in our discussion of individual strategies. The rating for this criterion, however, focuses just on costs and revenues from the public perspective, as this has a direct bearing on the financial ability or motivation for public-sector implementation. The possible ratings for this assessment are as follows:

- high cost
- medium cost
- low cost
- neutral
- low revenue
- medium revenue
- high revenue.

In assessing individual strategies against these ratings, we have used the following as a rough guideline. Net annualized costs or revenues on the order of hundreds of millions of dollars would be described as *high*, net annualized costs or revenues on the order of tens of millions of dollars would be described as *medium*, and net annualized costs or revenues on the order of millions or hundreds of thousands of dollars would be described as *low*. Any cost or revenue lower than this would be described as *neutral*. Recall, again, that the ratings are calibrated under the assumption that strategies would be implemented systematically throughout the region.

Short-Term Effectiveness in Reducing Congestion

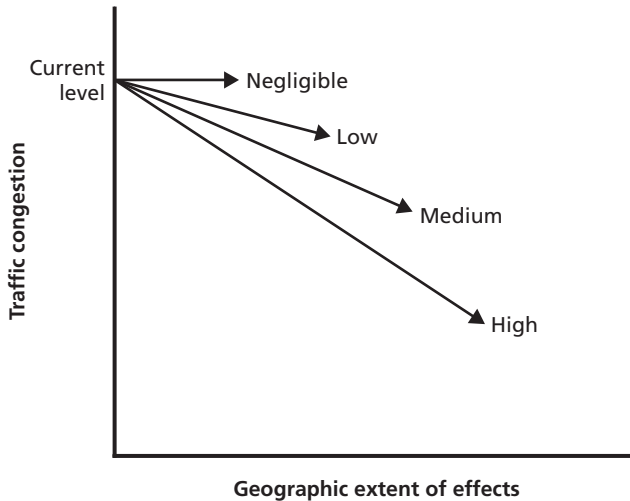
This assessment is used to describe the likely effectiveness of a strategy in achieving reductions in congestion in the immediate term, which

we define as a period of about one or two years. The possible ratings are as follows:

- negligible
- low
- medium
- high.

A rating of *negligible* indicates that a strategy would have little, if any, success in reducing traffic in the short term. A rating of *low* would be assigned if a strategy would produce small but noticeable reductions in traffic, perhaps limited to certain areas or facilities in the county. A rating of *medium* signifies that a strategy would result in more pronounced reductions in traffic, perhaps distributed more widely throughout the region. Finally, a rating of *high* would be applied to strategies that could yield significant reductions in traffic delays throughout most or all regions of Los Angeles. Figure A.1 illustrates these ratings.

Figure A.1
Short-Term Congestion-Reduction Ratings



Long-Term Effectiveness in Reducing Congestion

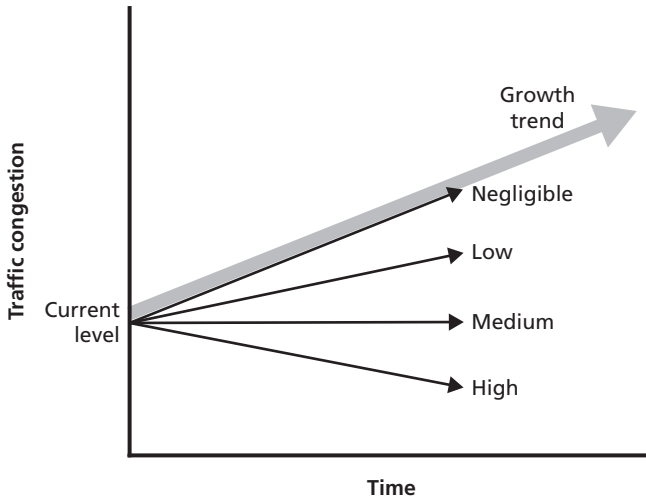
This assessment is used to describe the likely effectiveness of a strategy in achieving reductions in congestion over a period of several years or more. The possible ratings are as follows:

- negligible
- low
- medium
- high.

In assessing the effectiveness of alternative strategies in the long term, one must consider the likelihood that continued growth in population and economic activity in the region, absent significant transportation-policy interventions, will result in continued growth in traffic congestion as well. We have therefore defined our qualitative long-term effectiveness ratings in terms of how a strategy might influence the general trend toward additional travel and more-severe congestion in Los Angeles. A rating of *negligible* indicates that a strategy would do little, if anything, to slow the growth in congestion. A rating of *low*, in turn, is applied to strategies that may slow, but not necessarily halt, the growth of congestion. A rating of *medium* is used for strategies that could prevent congestion from growing worse in future years, while a rating of *high* indicates that a strategy could actually lead to long-term reductions in traffic congestion. These ratings are depicted in Figure A.2.

It is worth noting that, for many of the strategies considered in our review, the rating for long-term effectiveness in reducing congestion is lower than the rating for short-term effectiveness. This outcome stems from the phenomenon of triple convergence (as discussed in the main text of this book). The basic idea behind triple convergence is that many individuals currently choose to travel by other modes, routes, or times of day to avoid congested travel conditions in the peak periods. If a strategy results in short-term congestion relief, these individuals will soon notice that traffic is now flowing more freely. In response, many will alter their travel decisions, converging on the newly freed capacity from different times of day, routes, or modes, slowly but surely eroding

Figure A.2
Long-Term Congestion-Reduction Ratings



RAND MG748-A.2

the short-term congestion-reduction benefits produced by the strategy. For more discussion of triple convergence, see Downs (2004).

As a general rule, the only strategies immune to the effects of triple convergence are those—such as HOT lanes or cordon congestion tolls—that rely on financial signals to reduce demand. If travelers must pay more to travel on congested roads during peak periods, and if the prices are allowed to rise over time as needed based on the interaction of supply and demand, then triple convergence will not undermine the effectiveness of such strategies in the long term.

Note also that there are a few strategies for which the long-term effectiveness rating is higher than the short-term rating. This occurs in cases in which a strategy is potentially effective, but it would take a period of several years or more before the strategy could be implemented at a scale that would produce appreciable congestion-relief benefits. Consider, for example, the strategy of parking cash-out, in which employers that lease parking spaces on behalf of their employees offer the cash value of the lease to those employees who choose not to drive. Prior research (see, for example, Shoup, 1997) has demonstrated

that parking cash-out is extremely effective in reducing the number of employees who choose to drive to work alone. At present, however, the percentage of employers who lease spaces for their employees—and could therefore offer a parking cash-out option—is relatively small, thereby limiting the strategy’s short-term effectiveness. Yet early success among employers offering parking cash-out could stimulate municipal reforms in off-street-parking requirements for new developments, and this could slowly increase the number of employers in a position to offer parking cash-out. Thus, the long-term potential for parking cash-out to alleviate congestion is likely greater than the short-term potential.

Mobility, Accessibility, and Traveler Choice

While the primary focus of this book is on options for reducing congestion, the strategies considered are likely to influence other travel-related goals, such as mobility, accessibility, and traveler choice. The term *mobility* is used to describe the aggregate level of travel afforded by the transportation system. *Accessibility*, a closely related concept, refers to individuals’ ability to travel to destinations of interest, such as job sites, schools, health centers, stores, restaurants, and other cultural amenities—regardless of the mode or distance of travel required. When discussing accessibility, the needs of certain population groups—such as those unable to drive—are of particular interest. Finally, the term *traveler choice* describes individuals’ ability to choose among different routes, modes, or levels of service when making a trip. The purpose of this criterion is to provide a qualitative assessment of the effects of each strategy on one or more of these factors. The available ratings are as follows:

- very bad
- bad
- neutral
- good
- very good.

One of the primary reasons for including this criterion in our assessment framework is to make it clear that, while certain strate-

gies may have only a modest effect in reducing congestion, they may nonetheless be useful to pursue based on the other travel-related benefits they provide. For instance, most strategies designed to improve the quality of transit, bicycling, or pedestrian facilities are unlikely to provide long-lasting relief from congestion (consider, for example, that New York City has a superior public-transit system but still suffers severe traffic congestion). Even so, they could result in dramatic improvements in accessibility among some population segments, and they would improve the available choices for all travelers. In a similar vein, as noted, many of the strategies considered in this book—such as signal timing and control or peak-hour curbside-parking restrictions—may be less effective in the long term than they are in the short term due to the effects of triple convergence. Yet if such strategies increase the effective capacity of the transportation network, overall mobility would be enhanced over the long term even if congestion returns to previous levels. The purpose of this assessment criterion is to capture such effects.

Note that strategies reduce congestion may also have negative effects on mobility, accessibility, or traveler choice, as implied by the ratings of *bad* or *very bad*. For instance, mandatory cordon congestion tolls or driving restrictions would tend to reduce both mobility and traveler choice, at least among some population groups.

Safety

Safety is the first of four criteria related to other social goals that may be affected by the strategies discussed in this document (the other three are economic efficiency, environment, and equity). The safety criterion describes the degree to which a strategy will influence travel-related safety outcomes, such as accidents and fatalities. The available ratings include the following:

- very bad
- bad
- neutral
- good
- very good.

If the safety effects of a strategy appear to be negative—that is, meriting a rating of *bad* or *very bad*—we also consider whether complementary measures could help mitigate the negative effects. For example, strategies intended to encourage more bicycling may have negative safety outcomes given that the incidence (on a per-mile basis) and severity of bicycling accidents are higher than those for automobiles. Yet careful incorporation of bicycle-facility safety features and enhanced traffic-enforcement efforts may help reduce these negative effects. To describe the potential for mitigating the negative safety effects of a strategy with complementary measures, we employ three possible ratings:

- difficult to mitigate
- can partially mitigate
- can fully mitigate.

If the initial safety rating is negative, and if there are measures to partially or fully mitigate the negative effects, we assume that such measures would be pursued and modify the original safety rating accordingly, as shown in Table A.1. In this table, the initial ratings appear across the top rows, while the potential levels of mitigation are listed in the left-most column. The entries in the individual table cells represent the modified ratings based on the initial rating and the potential for mitigation.

Economic Efficiency

The purpose of this criterion is to describe the degree to which a strategy encourages greater economic efficiency in use of the transportation network. Two primary cases would lead to positive ratings for this criterion. First, any strategy that cost-effectively enhances the existing road network's capacity—in terms of throughput per lane-mile—would be judged as improving economic efficiency. In other words, such a strategy would help maximize return on the existing transportation infrastructure. Many of the TSM strategies fall into this category.

Second, any strategy that brings the marginal private costs of travel faced by the individual driver (e.g., fuel taxes, tolls, parking charges)

Table A.1
Potential Modification of Negative Safety Ratings

Potential to Mitigate Negative Effects	Initial Rating				
	Very Bad	Bad	Neutral	Good	Very Good
Difficult to mitigate	Very bad	Bad	N.A.	N.A.	N.A.
Can partially mitigate	Bad	Neutral	N.A.	N.A.	N.A.
Can fully mitigate	Neutral	Neutral	N.A.	N.A.	N.A.

NOTE: N.A. = not applicable.

into closer alignment with the social costs imposed by that travel (e.g., road wear, emissions, additional congestion imposed on other travelers) would be judged as improving economic efficiency. In economic terms, such a strategy would help internalize the current externalities associated with automotive travel, and this realignment of costs (that is, the shifting of social costs to private costs) would induce changes in travel behavior leading to net improvements in the level of social welfare afforded by the transportation network (for more discussion, see Downs, 2004). Several of the strategies involving congestion tolls or parking-price reforms would fall under this category. The ratings for economic efficiency are as follows:

- very bad
- bad
- neutral
- good
- very good.

As with the safety criterion, negative ratings for economic efficiency can be modified if complementary measures can help mitigate the negative effects. The modifications follow the same logic outlined in Table A.1.

Environment

This criterion focuses on the environmental effects of the alternative congestion-reduction strategies, with particular emphasis on local

emissions of air pollutants (such as carbon monoxide, nitrogen oxides, and particulate matter) and greenhouse gases. Note that the ratings are intended to reflect *aggregate* emissions as opposed to the level of emissions produced *per passenger-mile*. As a result, strategies that effectively increase system capacity and thus stimulate additional travel and emissions tend to perform poorly on this metric, whereas strategies designed to reduce the demand for automotive travel tend to perform much better. The ratings for environmental effects are as follows:

- very bad
- bad
- neutral
- good
- very good.

As with the safety and economic-efficiency criteria, negative ratings for environmental effects can be modified if complementary measures can mitigate the negative effects. The modifications follow the same logic outlined in Table A.1.

Equity

Most strategies will involve both direct and indirect costs and benefits. The purpose of the equity criterion is to evaluate whether these are distributed equitably. Special attention is focused on whether the relative distribution of costs and benefits associated with a strategy will work to the benefit or to the detriment of traditionally disadvantaged segments of the population, such as lower-income and racial or ethnic minority groups. Broadly speaking, strategies under which such groups would receive a significant share of the benefits would receive a favorable rating for equity effects. In contrast, strategies imposing costs that would be more difficult for such groups to shoulder would receive a negative rating. The ratings for equity effects are as follows:

- very bad
- bad
- neutral

- good
- very good.

As with the safety, economic-efficiency, and environment criteria, negative ratings for equity effects can be modified if complementary measures can mitigate the negative effects. The modifications follow the same logic outlined in Table A.1.

Stakeholder Concerns

This is the first of three criteria that consider potential obstacles that may make it more difficult to implement a strategy. The purpose of this criterion is to identify the degree to which certain stakeholder groups are likely, based on the relative distribution of costs and benefits associated with a strategy, to organize and exert political pressure in order to prevent that strategy's implementation. For example, lower-income advocacy groups and local retailer associations might be expected to lobby against the development of cordon congestion tolls, while homeowners' associations might organize to prevent the development of one-way-street configurations passing through their neighborhoods. The three ratings for this criterion are as follows:

- low
- medium
- high.

In cases in which the level of stakeholder concern is expected to be *medium* or *high*, we also consider whether complementary measures could help address the concerns in order to defuse the potential opposition. We define three possibilities:

- difficult to address
- can partially address
- can fully address.

If the initial stakeholder-concern rating is *medium* or *high*, and if reasonable complementary measures could partially or fully address those concerns, we assume that those measures would be implemented

in tandem and modify the initial stakeholder-concern rating accordingly. The logic for modifying the ratings is shown in Table A.2. In this table, the initial ratings are listed in the top rows, while the possibilities for addressing the concerns are listed in the left-most column. Each cell in the table represents the modified rating based on the initial rating of stakeholder concerns and the degree to which those concerns can be addressed.

General Political Obstacles

The purpose of this criterion is to assess the degree to which voters in general, along with the elected officials who represent them, are likely to support or oppose a given strategy. Many voters, for instance, may be opposed to the idea of paying additional tolls to travel during peak hours. As a result, cordon congestion tolls would likely face not only specific stakeholder concerns among lower-income advocacy groups and local retailer associations, but also general resistance among the voter population (and, by extension, their elected officials).

The three ratings for this criterion are as follows:

- low
- medium
- high.

As with the stakeholder-concern criterion, a rating of *medium* or *high* for general political obstacles can be modified if complementary

Table A.2
Potential Modifications of Stakeholder-Concern Ratings

Potential to Address Concerns	Initial Rating		
	Low	Medium	High
Difficult to address	N.A.	Medium	High
Can partially address	N.A.	Low	Medium
Can fully address	N.A.	Low	Low

NOTE: N.A. = not applicable.

measures can help address or overcome the political obstacles. The modifications follow the logic outlined in Table A.2.

Institutional Obstacles

This criterion reflects the degree to which institutional, jurisdictional, or legislative obstacles may make it more difficult to implement a strategy. Generally speaking, strategies that a single agency in the current legislative framework can implement pose much lower obstacles along this axis. If a strategy requires cooperation among multiple agencies, coordination across multiple jurisdictions, or new enabling legislation at the local, state, or national level, then implementation is likely to be much more difficult to achieve. The three ratings for this criterion are as follows:

- low
- medium
- high.

As with the stakeholder-concern and general-political-obstacle criteria, a rating of *medium* or *high* for institutional obstacles can be modified if complementary measures can help address or overcome the obstacles. The modifications follow the same logic outlined in Table A.2.

Current Status in the L.A. Region

The final criterion provides an assessment of each strategy's current level of implementation in the L.A. region. While a given strategy may, in theory, be capable of producing significant reductions in congestion, if the strategy has already achieved widespread adoption throughout the county, the marginal benefits of additional investment in the strategy are likely to be limited. The primary purpose of this criterion is to distinguish between those strategies that have already been leveraged to a significant degree and those for which ample opportunities for improvement still exist. The possible ratings for this criterion are as follows:

- none
- limited
- moderate
- significant
- advanced.

The *none* rating indicates that a strategy has not yet been implemented in the county. The *limited* rating is applied to strategies that have been applied in one or two places, or perhaps on a trial basis, but have not yet achieved widespread implementation. The *moderate* rating is used for strategies that are commonly applied but for which significant opportunities still exist for further implementation. The *significant* rating indicates that a strategy has been extensively applied, though there still may be some opportunities for further development. Finally, the *advanced* rating is applied to strategies for which the current level of implementation is so thorough that there is little, if any, additional benefit to be gained by further efforts.

Broadly speaking, strategies for which the current level of implementation is rated as *none*, *limited*, or *moderate* offer the greatest prospect for reducing congestion (assuming, that is, that they are also rated as effective in terms of their short-term congestion-reduction potential). If the current level of implementation for a strategy is rated as *significant*, then further implementation efforts would be warranted only if the strategy is especially effective in reducing congestion. For strategies whose current level of implementation is rated as advanced, additional investment would not be recommended.

Composite Strategy Ratings

While the 12 individual criteria ratings just outlined offer a comprehensive perspective on the advantages and limitations of alternative congestion-reduction strategies, they also add complexity to the task of comparing one strategy to another. To reduce the number of dimensions across which to compare strategies, we have therefore developed two composite ratings that are used in the main text of this book: one

that focuses on social outcomes and one that considers implementation obstacles. The social-outcome rating is based on a combination of the individual-safety, economic-efficiency, environment, and equity ratings. The implementation-obstacle rating, in turn, is based on a combination of the individual-stakeholder-concern, general-political-obstacle, and institutional-obstacle ratings. The final set of ratings used to compare and contrast strategies is as follows:

- net cost/revenue implications
- short-term effectiveness in reducing congestion
- long-term effectiveness in reducing congestion
- mobility, accessibility, and traveler-choice outcomes
- social outcomes (composite rating)
- implementation obstacles (composite rating)
- current status in the L.A. region.

The Social-Outcome Composite Rating

The social-outcome rating, which provides an average of the individual-safety, economic-efficiency, environment, and equity ratings, is constructed as follows. First, the score on each individual rating is converted to a numeric value (see Table A.3). The scores of the four individual strategies are then added together, and the resulting sum is translated into a composite rating (see Table A.4).

Table A.3
Social-Outcome Rating: Converting
Individual Ratings to Numeric Values

Rating	Numeric Score
Very bad	-2
Bad	-1
Neutral	0
Good	1
Very good	2

Table A.4
Social-Outcome Rating: Composite Scores

Sum of Individual Ratings	Composite Rating
-8 to -6	Very bad
-5 to -2	Bad
-1 to 1	Neutral
2 to 5	Good
6 to 8	Very good

The Implementation-Obstacle Composite Rating

The implementation-obstacle rating, which combines the individual-stakeholder-concern, general-political-obstacle, and institutional-obstacle ratings, is constructed as follows. First, the score on each individual rating is converted to a numeric value (see Table A.5). The scores of the three individual strategies are then added together, and the resulting sum is translated into a composite rating (see Table A.6).

Note that these scores are deliberately weighted toward the higher end. The logic is that even a single obstacle can make implementation difficult. Multiple obstacles will further compound this difficulty.

Table A.5
Implementation-Obstacle Rating:
Converting Individual Ratings to Numeric Values

Rating	Numeric Score
Low	1
Medium	2
High	3

Table A.6
Implementation-Obstacle Rating:
Composite Scores

Sum of Individual Ratings	Composite Rating
3	Low
4	Medium-low
5	Medium
6	Medium-high
7 to 9	High

Freeway-Ramp Metering

Ramp metering involves the use of traffic lights at freeway-entrance ramps, where signals are timed to even out the stream of vehicles merging into the main lanes. The intent is to reduce bottlenecks and disruptions that might occur if a large number of vehicles entered the freeway at the same time, which should, in turn, help maintain a smoother flow of traffic in the freeway lanes. Ramp meters may also discourage motorists from using the freeway for short distances, diverting them instead to arterial streets. There are at least three generations of ramp-metering technology (Caltrans District 7, 2007):

- *Fixed-time and time-of-day meters:* These are the simplest form of ramp meters. Metering periods and cycle lengths are preset based on historical data. These meters are not responsive to current freeway-flow conditions, but they will respond to long queues that fill up ramp storage and spill into adjacent arterial streets. When this occurs, a sensor in the ramp will trigger a signal to release cars from the ramp onto the freeway until the backup is relieved.
- *Traffic-responsive meters:* These systems have the same features as fixed-time meters but are also capable of adjusting metering rates based on current traffic conditions on the freeway itself. Controllers are able to override fixed timing plans when appropriate (that is, when current freeway conditions can accommodate more cars entering in close sequence). These systems detect conditions on the freeway only immediately upstream from the on-ramp and do not consider wider conditions throughout the freeway network.

- *SWARM*: These meters optimize traffic flow onto freeways by considering actual and predicted conditions throughout the freeway system. *SWARM* technology is also responsive to recurrent and nonrecurrent congestion. However, it requires a computerized communication center to calculate real-time adjustments along with a communication system to relay traffic detection from the field and metering plans back out to ramp meters.

Ramp metering was introduced in 1963 on the Eisenhower Expressway in Chicago. Los Angeles soon followed suit, deploying its first ramp-metering technology in 1969 (Caltrans District 7, 2007). By 1995, freeway-ramp metering had been implemented or was in the final design stages in 23 metropolitan areas in North America, including Atlanta, Dallas, Denver, Detroit, Fresno, Miami, Milwaukee, Montreal, New York, Ottawa, Phoenix, Riverside, Sacramento, San Diego, and Seattle (Piotrowicz and Robinson, 1995). Ramp metering has also been implemented in other countries, such as France, the Netherlands, Japan, Australia, and South Africa. In many cases, ramp metering has been implemented as part of a suite of technology-enabled traffic-management strategies (Papacostas and Prevedouros, 2001).

Evaluation of Strategy

Cost/Revenue Implications

Rating: Medium cost. The costs of ramp-metering systems vary depending on the level of technology employed as well as the scope of implementation, increasing significantly with the addition of communication networks, surveillance systems, and centralized computing required for *SWARM* systems. Several studies have found that precise timing is critical for achieving and maintaining freeway flows (Hellinga and Van Aerde, 1995) and that, under certain circumstances, improper timing can negate any benefits of metering (Banks, 1988). This underscores the importance of ongoing expenditures related to operations, maintenance, and other associated costs.

An evaluation of ramp metering in the Twin Cities area sponsored by the Minnesota Department of Transportation (MNDOT et al., 2001) estimated system capital costs on the order of \$63 million and annual operating costs of \$1.5 million for a system of 430 ramp meters, 3,500 traffic sensors, 230 closed-circuit television (CCTV) monitors, and a traffic-management center (TMC). Note, however, that the CCTV surveillance system and TMC were the two highest-cost items, and both of these elements can support other traffic-management strategies, such as incident-management systems and advanced traveler-information systems. As such, these high costs may be spread across multiple programs, and the actual percent attributed to ramp-metering systems will likely differ from case to case, depending on agency-specific cost-allocation protocols.

Short-Term Effectiveness in Reducing Congestion

Rating: Medium (uncertain). Ramp metering can be effective in managing congestion, both by increasing aggregate vehicular throughput and capacity and by reducing crash rates on the freeway main lines. Several studies have documented flow improvements and delay reductions with the use of ramp metering. In an evaluation of the Minnesota Department of Transportation's ramp-metering program in the Twin Cities, for example, it was demonstrated that the technology increased freeway throughput by 9 percent on average and by 14 percent during peak periods. This translated to more than 25,000 hours of annual travel-time savings for the region (MNDOT et al., 2001). Another study of Denver's ramp-metering system found that speeds increased up to 58 percent when the meters were turned on (Corcoran and Hickman, 1989).

Such dramatic improvements, however, are not certain. A simulation of ramp metering in Orange County, California, for example, showed that significant levels of traffic had to be diverted to arterial streets in order to maintain efficient flows on the freeway network and that improvements were negligible if parallel streets were already operating at or above capacity (Nsour et al., 1992). Another study reached similar conclusions, finding that passenger hours dropped by 6.3 percent in cases in which there was unused capacity on alternative streets

but actually *increased* by 3.1 percent in cases in which the parallel arterials were operating at capacity (Alexiadis and Schmidt, 1994).

Because ramp-metering effectiveness can depend on arterial-street conditions, we rate this strategy as having *medium* effectiveness in short-term congestion reduction but also describe the rating as being *uncertain*.

Long-Term Effectiveness in Reducing Congestion

Rating: Low. Ramp metering is intended to reduce delays on the freeways. To the extent that it is effective in this regard, however, its benefits will tend to be undermined in the longer term based on the phenomenon of triple convergence. Moreover, ramp metering will do little to stem longer-term increases in congestion resulting from continued population and economic growth.

Mobility, Accessibility, and Traveler Choice

Rating: Good. Ramp metering, if successfully implemented, will enhance mobility by increasing the freeway network's effective capacity. Note, however, that ramp metering improves freeway performance by managing the rate of vehicles using the on-ramps. If this causes traffic to back up onto the arterial system, traffic on the surrounding surface streets may be impaired. In addition, ramp meters may have a limiting effect on traveler choice by diverting short trips off of the freeway and onto local streets (Papacostas and Prevedouros, 2001). Despite these problems, improved freeway flows—the benefits of which accrue to automobiles as well as any trucks and buses using the freeways—can provide increased mobility across the region. For this reason, we rate ramp metering as having good effects in this category.

Safety

Rating: Very good (uncertain). Several studies have shown that ramp metering can lead to significant improvements in vehicular safety, especially in terms of reductions in rear-end and sideswipe collisions (Caltrans District 7, 2007). For example, an annual reduction of more than 1,000 crashes, or approximately four crashes per day, was observed in the Twin Cities area after ramp metering was imple-

mented (MNDOT et al., 2001). Another study found that accidents on a segment of I-35 in Minnesota dropped from 421 to 308 per year as a result of ramp metering (Piotrowicz and Robinson, 1995). In most studies, however, it is unclear whether additional factors may have contributed to the observed reduction in crashes. Moreover, while ramp metering smoothes traffic flow in merge zones (C. Lee, Hellinga, and Ozbay, 2006), it will also tend to increase average vehicular speeds, and few studies have evaluated the effects on fatal versus nonfatal crashes. Ramp metering therefore receives a rating of *very good* for safety effects, but we describe this rating as being *uncertain*.

Economic Efficiency

Rating: Good. Ramp metering effectively enhances the capacity of the existing freeway network at far lower cost than adding new lane-miles. It therefore improves the return on existing transportation-infrastructure investments.

Environment

Rating: Bad/difficult to mitigate—>bad (uncertain). Evidence on the environmental benefits of ramp metering is mixed. On one hand, by smoothing the flow of freeway traffic, it can help reduce the wasted fuel and emissions that occur with stop-and-go conditions. On the other, ramp meters force vehicles to idle on the on-ramps as they wait their turn to enter the freeway, and this will result in an increase in fuel consumption and emissions. For example, a study of the Twin Cities' experience with ramp metering suggested that, while improving freeway flows led to a net annual savings of 1,160 tons of emissions, the queuing of vehicles at on-ramps led to an *increase* in gasoline consumption of 5.5 million gallons per year (MNDOT et al., 2001). Moreover, if improved freeway flows result in more drivers trying to use the freeway system during peak hours, any initial benefits with respect to reduced gasoline consumption or emissions for vehicles in the main lanes will slowly be eroded. For this reason, we rate the strategy as *bad* with respect to environmental concerns over the longer term, though we also describe the rating as *uncertain*.

Equity

Rating: Bad/difficult to mitigate—>bad. Ramp metering provides preferential treatment for through traffic, and this leads to an unequal distribution of costs and benefits. As a general rule, suburban drivers—who tend to travel longer distances on the network and often enter the freeway network farther upstream, where ramp meters may not be needed—will reap a significant share of the benefits. Urban drivers, in contrast, do not fare nearly so well, as they often make shorter trips and must enter the freeway at the most congested on-ramps (Papacostas and Prevedouros, 2001). Moreover, residents living near freeway interchanges bear the costs of potential traffic queues on arterial streets that result from ramp metering (D. Levinson and Zhang, 2006).

Stakeholder Concerns

Rating: Medium/can partially address—>low. Neighborhood groups in areas near freeway ramps may raise objections if ramp meters cause traffic to spill over into the surrounding arterial network. This concern can be at least partially mitigated through timing plans that coordinate arterial and freeway operations to ensure that queues do not exceed the number of vehicles that a ramp can hold at once.

General Political Obstacles

Rating: Low. Introduction of ramp metering may raise objections among motorists if they perceive that controlled, intermittent access will cause overall travel delay. This is not likely given that state DOTs widely use ramp metering and the public generally accepts it. Additionally, any delay imposed on individual motorists (real or perceived) is small enough that any opposition should be minimal.

Institutional Obstacles

Rating: High/can partially address—>medium. Efforts to coordinate freeway-ramp metering with arterial-street operations are likely to face significant institutional obstacles, as different agencies or jurisdiction often manage them. To begin with, it is necessary to develop compatible policy aims, even though the various participants may have distinct and possibly competing mandates. For example, effective

coordination of traffic-signal timing and ramp metering will require agreement about the circumstances under which one system may be treated as subordinate to the other in order to maximize overall system efficiency. In addition, the different participants may rely on different technology platforms, it necessary to establish and implement a common communication protocol. Illustrating the nature of such challenges, in the late 1990s, a field-operation test for coordinating freeway- and arterial-signal controls was attempted in Irvine, California. Institutional barriers between Caltrans, participating local governments, funding partners, and technology vendors were so high that the planned technologies failed to be implemented. State and local agencies had difficulty with such issues as the development of memoranda of understanding, establishing clear lines of authority and responsibility, and resolving the different scheduling needs of the various institutional partners (MacCarley et al., 2002).

Such obstacles can be mitigated, at least to some extent, with clear technical specifications and explicit language on authority and responsibilities in contractual agreements. Increasingly, advances in technology and computational methods may also help bridge these institutional positions.

Current Status in the L.A. Region

Rating: Significant. Ramp metering was first implemented in Los Angeles in 1969, and it has now been employed through the county. Caltrans District 7, which encompasses Los Angeles and Ventura counties, manages the most extensive ramp-metering system in the state, including 870 on-ramp meters as well as 19 freeway-to-freeway connector meters. Almost half of the metered ramps include nonmetered HOV bypass lanes, which can be converted to metered lanes for additional capacity as needed. About 370 on-ramps in District 7's jurisdiction are not currently metered, owing to such factors as geometric constraints, low traffic volumes, or lack of funding (Caltrans District 7, 2005).

District 7 is currently deploying and testing SWARM technology on various sections of main-line freeways that are experiencing significant increases in traffic volume. In December 2006, SWARM

was tested on segments of SR-210 as part of the state's strategic growth-management plan program. Before-and-after evaluations were conducted to quantify delay reductions and time savings, provide on-ramp volumes and queue-count data, identify traffic flows and bottlenecks, and recommend geometric and lane-striping improvements (Caltrans District 7, 2007). At the time of this writing, the results have not yet been published.

Interaction with Other Strategies

Because sophisticated ramp-metering systems rely on a centralized advanced traffic-management system (ATMS), they complement other strategies that also require automated detection, surveillance, and control functions. Examples include incident-management systems (see Appendix B10) and advanced traveler-information systems (see Appendix B15). Ramp metering can also be augmented with HOV ramp lanes that permit buses and carpools to bypass queues at ramp meters. This increases system capacity and reduces queuing on ramps.

Depending on the timing plans, ramp metering may conflict with efforts to synchronize arterial street traffic signals (see Appendix B2). This can be mitigated through coordinated freeway and surface-street operations, though such coordination is complex.

Signal Timing and Control

The timing and control (or synchronization) of traffic signals offer an important tool for managing and improving traffic flow on the arterial system. *Signal timing* refers to the duration and sequencing of lights at an intersection to control the flow of traffic moving in different directions through that intersection. The term *synchronization* describes the coordinated timing of multiple signals to achieve more-efficient flow through a series of intersections. Through timing and synchronization, signals can be programmed to reduce traffic delays over an entire network or to allow priority throughput along specific routes or at specific bottleneck points.

The most basic traffic signal—a pretimed signal—assigns the right-of-way at intersections according to a predetermined, fixed schedule that is often based on historic traffic patterns. Pretimed signals can also be synchronized to allow, for example, priority throughput in peak directions at peak periods of the day. Pretimed signals cannot recognize or adapt to unexpected traffic fluctuations, however, and any adjustments to the signal cycles must be performed manually in the field.

More-advanced traffic-actuated signals, in contrast, are capable of adjusting and assigning the right-of-way based on real-time changes in traffic patterns. These signals can be timed and controlled to respond to recurrent traffic congestion, unexpected demand, or incidents and emergencies. Other benefits include improved safety for motorists, bicyclists, and pedestrians because traffic flows can be smoothed out to minimize vehicular conflicts and to provide timed crossings for pedestrians when needed. In addition, traffic-actuated signal timing

and synchronization can also be used to provide signal priority or preemption for transponder-equipped transit vehicles.

Unlike pretimed signals, actuated signals rely on some additional technological components. First, field elements, such as sensors and detectors, are needed to collect information on traffic conditions; for example, inductive-loop detectors embedded under streets and intersections are commonly used to monitor flows by detecting the speed and number of vehicles that pass over the loops. Other nonintrusive detection devices include infrared sensors, Doppler or radar sensors, and video sensors (CCTV cameras and other visual monitoring systems). The second component of actuated signal synchronization is the communication system that relays information collected from sensors and detectors. These systems can use either hard-wired (e.g., telephone lines, fiber-optic cables) or wireless communication. Information is relayed to the third component, a centralized control center that receives and processes information to determine changes to signal timing. Depending on the system's sophistication, the control center may then communicate the new timing parameters to traffic signals for real-time adjustments. Systems of traffic-actuated signals are commonly described in terms of four generations of capabilities (Papacostas and Prevedouros, 2001):

- *First-generation signals:* These are the most common systems developed in metropolitan areas (Papacostas and Prevedouros, 2001; Homburger et al., 2007). These systems use a set of pre-programmed timing plans for various times of the day or for specific demand parameters. The timing programs are stored in memory, and, as sensors detect traffic-volume thresholds, alternative plans are implemented as necessary from the menu of timing plans.
- *Generation 1.5 signals:* These estimate signal timings in a quasi-online mode. Data are gathered and uploaded from field detectors, optimization analysis is conducted, and a new timing plan is computed. The system then compares the new plan to the current timing plan, and an operator must decide whether the improvement is to be implemented temporarily or permanently (Hom-

burger et al., 2007). This level of capability is commonly available in new systems deployed today (FHWA, 2003c).

- *Second-generation signals:* These provide traffic-adaptive control in real time based on data collected by traffic detectors and transmitted online. These systems use prediction models to determine near-term (e.g., 15 minutes) changes in traffic demand. Current conditions and predictions are then used to compute revised signal timings (Homburger et al., 2007).
- *Third-generation signals:* These provide quicker response to real-time traffic conditions and are therefore particularly useful for handling nonrecurrent demand spikes. Third-generation systems, however, are often unstable because they are particularly sensitive to changes in the data (Papacostas and Prevedouros, 2001).

Evaluation of Strategy

Note that traffic-signal synchronization has been extensively developed and deployed in the city of Los Angeles, as well as several other, smaller cities. There is near-complete coverage using current-generation technology in many areas, and further expansion is being planned in the near term. Accordingly, the assessments that follow consider both marginal improvements to the system in the city of Los Angeles and the introduction of upgraded systems for other cities in the region that do not currently employ advanced signal-control strategies.

Cost/Revenue Implications

Rating: High cost. The costs of constructing new traffic signals vary depending on the complexity of the intersection, the type of controller units used, and the type of wiring. New signal installations can range from \$75,000 to \$175,000 (in 2004 dollars) depending on the sophistication of the technology. Because of the additional expense for detectors and controllers, traffic-actuated signals are typically two to three times more expensive than pretimed signals (Homburger et al., 2007). Additionally, underground detectors are expensive to install and operate, requiring extensive construction work at the outset as well as

ongoing maintenance and inspections. Because outdated timing plans or technical malfunctions are the cause of most delays on an optimized network (Vasudevan and Chang, 2006), routine updates and maintenance are critically important to ensure proper operation. The cost of retiming a signal varies but is typically on the order of several thousand dollars. The San Francisco Bay Area Metropolitan Transportation Commission, for instance, reported costs of around \$2,400 per signal (Heminger, 2006); in Washington, D.C., the reported cost was \$3,500 per signal (Sunkari, 2005). Nationally, the average cost to retime each signal is about \$3,000 (NTOC, 2005). When these initial installation and ongoing maintenance costs are multiplied for numerous intersections throughout a city, the total required expense quickly escalates. Additional costs associated with signal timing and control include staff training, office equipment and installation, and supporting computers and software.

Short-Term Effectiveness in Reducing Congestion

Rating: High. According to a study from Oak Ridge National Laboratory (Chin et al., 2004), poor traffic-signal timing accounts for about 10 percent of the traffic delays on major U.S. roadways. Improving signal timing can therefore achieve significant short-term reductions in congestion. In Syracuse, New York, for example, the introduction of a communication network allowing centralized control of intersection signals resulted in travel-time savings of 34 percent (DMJM Harris, 2003). An earlier FHWA-sponsored review of signal timing and control applications found that the incorporation of advanced signal systems can reduce travel time by 8 to 15 percent and increase travel speed by 14 to 22 percent (MITRE, FHWA, and USDOT, 1996).

During the mid-1990s, engineers at LADOT (1994) conducted an in-house evaluation of the city's Automated Traffic Surveillance and Control (ATSAC) system. Their results indicated that the upgraded timing and synchronization offered by ATSAC, when compared with the previous generation of pretimed signals, led to a reduction in travel times of 18 percent along with an increase in travel speed of 16 percent. More recently, LADOT has begun a program of upgrading the synchronizing of many traffic signals. When LADOT resynchronized

signals along Olympic, Venice, and Victory Boulevards in 2004, for instance, average traffic speeds along these routes increased by 10 to 20 percent, while average travel times were reduced by 14 to 17 percent (LADOT, undated[b]). Continued efforts to improve the timing and synchronization of signals in Los Angeles are ongoing, as discussed next.

Long-Term Effectiveness in Reducing Congestion

Rating: Low. Signal timing and control is useful for maximizing vehicular throughput and system efficiency. In the long run, however, unless complementary policies to reduce automotive demand are put into place, the effects of triple convergence can be expected to slowly erode any congestion-reduction benefits achieved through improved signal timing and control.

Additionally, traffic signal timing and control strategies are reported to be highly effective for incident and corridor management, but the observed level of benefits diminishes with traffic saturation and general congestion (Kim, 2007). Few studies have evaluated the long-term effectiveness of traffic-signal control and synchronization, as most tend to measure traffic conditions before and then immediately after traffic-signal implementation.

Mobility, Accessibility, and Traveler Choice

Rating: Very good. Traffic-signal timing and synchronization effectively enhance the capacity of the existing arterial network, and this promotes greater mobility. The benefits of effective signal control accrue not only to drivers but also to transit users. The transit benefits can be enhanced to an even greater extent if signal priority is granted to high-capacity vehicles, as is the case with Metro Rapid buses. This bolsters both accessibility (among transit users) and traveler choice.

Safety

Rating: Good. Traffic-signal coordination produces safety benefits by ensuring orderly movement of traffic and reducing the frequency of certain types of accidents, such as right-angle and pedestrian collisions. Timing control can also provide sufficient clearance for pedestrians in

crosswalks and can give priority to, and thus minimize vehicular conflict with, emergency responders.

Economic Efficiency

Rating: Good. Optimizing the timing and control of traffic signals serves the goal of economic efficiency in several ways. First, it increases the capacity of arterial networks by granting rights-of-way where needed most, thereby serving a greater number of motorists for a given level of investment in arterial lane-miles. Second, if used to provide priority for high-capacity vehicles, traffic-signal control can promote greater total passenger throughput.

Environment

Rating: Neutral. To the extent that traffic-signal synchronization can reduce vehicular idling and the resultant emissions (Papacostas and Prevedouros, 2001), it can be expected to have positive environmental effects. LADOT officials estimate, for example, that the ATSAC system in Los Angeles reduces carbon emissions by 912,000 metric tons per year (L.A. Office of the Mayor, 2007b). Through the effects of triple convergence, however, the short-term reduction in traffic delays resulting from improved signal timing and synchronization will lead to more vehicular trips in the long run, thereby undermining the shorter-term environmental benefits. For this reason, we rate the environmental effects as *neutral*.

Equity

Rating: Good (uncertain). Signal timing and control can produce equity benefits if the technology is used to grant priority to transit vehicles, whose users are more likely to come from lower-income and other underrepresented groups. Because there is no guarantee that cities will choose to implement signal prioritization for transit vehicles, however, we describe our rating of *good* as being *uncertain*.

Stakeholder Concerns

Rating: Medium/can partially address—>low. Stakeholder concerns should not be significant, as the implementation of traffic-signal

synchronization is unlikely to inconvenience or impose costs on any particular stakeholder groups. One possible exception is that neighborhood groups may oppose signal timing that allows higher traffic throughput on arterials that run along or in their residential areas. These concerns can be at least partially mitigated, however, by the enforcement of speed limits.

General Political Obstacles

Rating: Low. Traffic-signal optimization is not likely to generate opposition among the general public or elected representatives because it leads to benefits in the form of reduced congestion delays that most voters will appreciate.

Institutional Obstacles

Rating: High/can partially address—>medium. Effective signal timing and control is not difficult to implement in a single city. At the regional level, however, institutional obstacles are much higher, especially in a county with numerous municipal jurisdictions, such as Los Angeles. A coordinated regional system will require communication and shared decisionmaking across multiple cities, especially where one city's network of signals abuts another's network. A major institutional challenge is the mutual coordination of signals at the border of two cities in cases in which each city retains individual control over its own signal-timing plans. For reasons related to self-interest as well as liability, cities are not likely to cede control over their timing plans. Additionally, signal synchronization for multimodal management (cars and transit) will also require collaboration among the different agencies and departments that oversee different modes. These institutional obstacles can be lessened with regional leadership and funding and with both formal and informal agreements between agencies.

Current Status in the L.A. Region

Rating: Significant. Traffic-signal timing and control in the L.A. region is left to individual municipalities, with some regional coordination by Metro and LACDPW. The extent of implementation and the sophistication of signal control range considerably among cities

and unincorporated areas of the county. For example, the ATSAC system in the city of Los Angeles was developed in-house and now includes close to 75 percent of all traffic signals within the city boundaries (Fisher, 2006). Three other cities—Pasadena, West Hollywood, and Inglewood—have merged their signal timing and control with ATSAC. Other municipalities in the region maintain control over their own systems but also feed traffic information to ATSAC.

In unincorporated areas, LACDPW currently has 50 automated signals that communicate with its centralized monitoring and control system. LACDPW plans to expand its current system to include 900 additional signals with wireless communication, all in the South Bay. This project is expected to cost \$10 million and should be completed in 2010. In partnership with LACDPW, Metro provides grants to some small cities to install and operate traffic signal-timing systems, with cities expected to provide a 20-percent funding match. LACDPW administers the grants and can install and operate these cities' systems at their request. To coordinate these systems, LACDPW has been leading the development of an information-exchange network that consolidates information exchange between participating cities for traffic-signal synchronization along arterials. To date, participants in the information-exchange network include L.A. County as well as the cities of Los Angeles, Pasadena, West Hollywood, and Inglewood (White, 2007).

The relationship between the signal-timing systems managed by LADOT and LACDPW illustrates both the institutional challenges and opportunities for this strategy in a multijurisdictional setting. Across these two systems, intersection signals are coordinated but not centrally controlled (White, 2007). Though technically possible, centralized control has, to date, remained politically infeasible, in large part for reasons of autonomy and liability. (For instance, if the county were to control signals in the City of Los Angeles and an accident occurred at one of the intersections, the city might be sued even if were not in control of the signal timing.)

In the region, the City of Los Angeles has been the most aggressive in developing and deploying an advanced system of signal timing and synchronization, beginning with early efforts in anticipation of the

1984 Olympics and continuing with the development and improvement of ATISAC through the 1990s. More recently, LADOT initiated a program called Operation Bottleneck Relief (OBR) to identify the most heavily congested intersections in the city. A primary objective of OBR is to relieve congestion at these intersections using traffic-signal timing where possible, followed by recommendations for additional improvements, such as street widening, restriping for additional lanes, and restricting curb-side parking during peak hours. The city identified 98 intersections for initial evaluation and improvements. Thirty-six percent of these intersections demonstrated successful congestion relief due to signal timing, yielding an average reduction in delay of about 32 percent, while another 14 percent required additional operational or capital improvements (Fisher, 2006). For eight of the bottlenecks studied, a significant source of the congestion was overflow from adjacent freeway ramps, where restrictive on-ramp metering plans throttled the speed at which ramp traffic could enter the freeways. Caltrans is currently working to coordinate ramp metering with arterial traffic-signal timing to help mitigate this problem (Quon, 2007). Following the initial OBR evaluation, LADOT plans to study 60 new OBR intersections per year, using successively lower thresholds for identifying candidate hot spots (Fisher, 2006).

In addition, the City of Los Angeles recently received \$150 million for traffic-signal synchronization improvements from state bond revenues. The funds will allow the city to add, by 2011, 1,117 signals to the ATISAC system, upgrade 1,256 more signals to the most recent technology, and add 340 traffic-tracking cameras to help monitor intersections (California Office of the Governor, 2007). These efforts are expected to reduce traffic delays by about 30 percent for local commuters (L.A. Office of the Mayor, 2007b).

These efforts are directed primarily at managing traffic signals on arterial streets. Metro, meanwhile, is leading an effort to manage congested corridors (which include arterial intersections with freeway ramps) and multimodal traffic operations. Through its RIITS program, the agency is developing and implementing a network of open communication for use by all modes of transportation; RIITS coordinates freeway operations, arterial-signal synchronization, transit opera-

tions, and emergency-service operations. The system also supports the Integrated Corridor Management (ICM) initiative, a pilot project that includes the I-10 and I-710 corridors, and 15 to 20 other candidate corridors countywide (P. Liu, 2007).

Interaction with Other Strategies

Traffic-signal timing and coordination maximize system efficiency by smoothing traffic flows across a network of arterials and intersections. Such a tool can be implemented in parallel with other strategies intended to enhance the efficiency of the transportation system, such as ramp metering (see Appendix B1), one-way street alignments (see Appendix B8), and incident-management programs (see Appendix B10). Signal control can also boost the effectiveness of demand-side strategies, including prioritizing signals for BRT systems (see Appendix B25) and bicycle and pedestrian improvements (see Appendixes B27 and B28).

High-Occupancy Vehicle–Lane Strategies

HOV lanes, also known as carpool lanes, are designated lanes in a facility that can be used only by HOVs, such as carpools, vanpools, or transit buses. In some cases, the high-occupancy limit is defined as two or more people (HOV 2+), while, in others, it is defined as three or more people (HOV 3+). HOV-lane restrictions may apply at all times, or they may apply only during peak travel hours. It is also possible to structure HOV lanes with an HOV 2+ requirement during off-peak hours and an HOV 3+ requirement during peak hours (SCAG, 2004). While HOV lanes are most commonly implemented on freeways, it is also possible to develop HOV lanes on arterials (Turnbull, 2002b). HOV lanes are intended to accomplish several goals (Parsons Brinckerhoff, 2002):

- Use capacity more effectively by boosting the average occupancy of vehicles traveling in a lane.
- Provide travel-time savings and improve travel-time reliability for HOV-lane users, thereby encouraging more carpooling, vanpooling, and bus ridership.
- Improve air quality by reducing the number of SOVs.

The earliest HOV lanes began as demonstrations in 1969 in New Jersey and Virginia to improve public-transit operations and travel time. HOV-lane facilities have since been implemented mostly in large metropolitan areas and in freeway corridors where traffic congestion is most severe. About 130 HOV facilities operate in 23 metropolitan areas

nationwide. Los Angeles, Seattle, and San Francisco have implemented the most HOV lane-miles to date (Fuh and Obenberger, 2002).

Because SOV drivers are reluctant to relinquish existing general-purpose lane capacity, HOV lanes are most often implemented in concert with new capacity additions rather than through the conversion of existing lanes. Creating new HOV lanes, however, requires many years of planning and construction and thus would not qualify as a short-term strategy for congestion relief in the context of this study. There are, however, several HOV-related strategies that could be planned and implemented relatively quickly. We consider the following:

- *Converting general-purpose lanes to HOV lanes:* This strategy could boost the effective passenger throughput on a facility (either a freeway or an arterial) and, in turn, relieve congestion, provided that (1) the creation of an HOV lane would stimulate at least some existing SOV drivers to switch to carpools (or, alternatively, vanpools or transit buses) to take advantage of the HOV lane's greater travel speeds and (2) the combination of existing carpools plus new carpools using the facility would be sufficient to make effective use of the capacity of the newly dedicated HOV lane. As noted, however, any such conversion would likely engender significant resistance among SOV drivers wary that traffic conditions in the remaining general-purpose lanes would become worse.
- *Changing HOV passenger limits:* The demand for many existing HOV facilities in greater Los Angeles is already at or above capacity, thus reducing the potential for travel-time savings in the lanes and the ability to encourage more ride-sharing in the congested corridors. To relieve congestion in existing HOV lanes, it is possible to increase the minimum occupancy criterion from HOV 2+ to HOV 3+. This change could be applied during all hours or possibly during just the peak travel hours. Raising the HOV occupancy limit could lead to increased person throughput, provided that a large share of two-person carpools would be willing to shift to three-person carpools, vanpools, or bus transit. There is also the danger, however, that some share of two-person carpools would return to single-occupant driving once they can no longer use the

carpool lanes due to the raised minimum, and this could degrade overall facility performance. Consideration of this strategy thus merits careful analysis on a case-by-case basis.

- *Changing HOV passenger definitions:* Most HOV occupancy definitions are framed as two or more persons or three or more persons. Thus a parent and child (or a parent and two children, in the case of HOV 3+) are usually considered to constitute a carpool. Yet one of the primary motivations for the establishment of HOV lanes is to encourage the formation of carpools among individuals who would otherwise drive separate vehicles. This is clearly not the case with child passengers. This suggests a rationale for changing the definition of carpool occupancy from the number of persons in the car to the number of adults (the number of licensed drivers would be even more effective, though obviously harder to enforce). Such a change would not be helpful for underutilized HOV lanes, of course. For HOV lanes where the demand exceeds the capacity, however, removing parent-child carpools would free up space in the HOV lanes, thereby improving travel speed and increasing travel-time savings. This, in turn, could help induce the formation of additional carpools among adult drivers who currently travel alone.
- *Eliminating the clean air–vehicle exemptions:* Under California state law, drivers of qualifying clean-air vehicles, such as gasoline-electric hybrids or vehicles that run on natural gas, are allowed to use HOV lanes in single-occupant mode. This exemption from the normal occupancy requirements was originally designed as an incentive to increase the rate of adoption of lower-emission vehicles. With recent upswings in the price of gasoline, however, this additional incentive may no longer be needed and, in fact, may be counterproductive. As additional clean-air vehicles reduce available capacity in the HOV lanes, the potential for travel-time savings decreases correspondingly, and this reduces the incentive for other drivers to form carpools. As a result, more travelers may choose to travel in single-occupant mode, exacerbating both congestion and air-quality issues.

- *Increasing enforcement of HOV occupancy rules:* Metro reports that the percentage of HOV users violating the minimum occupancy requirements is just 3 percent (Parsons Brinckerhoff, 2002). Some of the experts with whom we spoke during the course of this study suspect, however, that the violation percentage may be higher than this. If so, increasing the level of enforcement (or, alternatively, charging even higher fines for deliberate violators who are caught) would reduce violations, thereby improving travel conditions for legitimate HOV users and encouraging additional mode-shift from single-occupant driving to carpooling, vanpooling, or bus transit in the lanes.

Note that the appropriateness of the different short-term strategies outlined here would likely vary on a case-by-case basis. In the following discussion, we attempt to develop ratings for various outcomes under the assumption that the most sensible strategies would be employed in a given context.

Evaluation of Strategy

Cost/Revenue Implications

Rating: Low cost. While the longer-term strategy of building new HOV lanes would be quite expensive, the shorter-term HOV-related strategies outlined here can be achieved for a relatively low cost. Perhaps the most expensive option would be to increase enforcement efforts, which would likely require additional highway-patrol officers, but increased collection of violation fines would at least partially offset these costs. Thus, the strategies are rated as *low cost*.

Short-Term Effectiveness in Reducing Congestion

Rating: Low (uncertain). The creation of new HOV lanes—by virtue of expanding available capacity—can result in significant reductions in traffic across all lanes. The effects of the shorter-term strategies considered here, such as converting general-purpose lanes to HOV lanes or increasing the occupancy requirement from HOV 2+ to HOV 3+,

are less clear and may well vary from one facility to the next. In general, higher-occupancy vehicles eligible to use HOV lanes do enjoy faster and more reliable speeds. For example, in a recent study of HOV lanes in L.A. County, all of the HOV routes analyzed provided at least some travel-time savings to the carpool-lane users. Moreover, unlike many of the general-purpose lanes on the same facilities, the studied HOV lanes offered average travel-speed conditions that could be considered free-flowing, as opposed to congested (Parsons Brinckerhoff, 2002).

To evaluate the effectiveness of HOV-related strategies in reducing congestion, however, it is also necessary to consider outcomes in the remaining general-purpose lanes, and here the results can vary to a significant degree. Research by Dahlgren (1995), for example, suggests that HOV lanes can provide overall travel-time savings across all drivers if (1) the facility in question is already very congested, and (2) there is a large percentage of existing or prospective carpools, vanpoolers, or transit users who would use the HOV facility once in place. Absent these conditions, the implementation of HOV lanes—while clearly benefiting higher-occupancy travelers—may degrade travel conditions for those in the general-purpose lanes.

As an illustration of the potential negative effects, in 1976, one of the four lanes on the Santa Monica Freeway was temporarily converted to an HOV facility. This conversion resulted in a 65-percent increase in the number of carpools, a 250-percent increase in transit use along the freeway, and a 10-percent decrease in peak-period vehicle trips, all seemingly positive outcomes. Before the conversion, however, only 3 percent of the vehicles on the freeway were carpools, and bus passengers accounted for only 0.8 percent of the facility's travelers, so the large percentage increases in these modes translated to quite modest numerical increases. As a result, the HOV lane—representing 25 percent of the freeway's capacity—carried just 6 percent of the overall vehicular flow, including carpools and transit users. Congestion in the remaining three general-purpose lanes increased noticeably, and the subsequent public outcry led to the reversion of the HOV lane to a general-purpose lane (Dahlgren, 1995). On the other hand, more-recent studies indicate that HOV lanes have encouraged drivers to adopt congestion-reducing behaviors, such as joining a carpool or vanpool and using

transit. Surveys of L.A. County carpool-lane users found that more than 50 percent previously drove alone in the general-purpose lane on the same freeway. A University of California, Irvine, study found that a similar percentage of drive-alone commuters converted to carpooling when Orange County first opened its carpool lanes (Parsons Brinckerhoff, 2002).

Drawing on the mixed evidence, we conclude that the shorter-term strategies outlined here would likely offer, at best, a modest improvement in traffic conditions. Because the specific outcomes are likely to vary from one facility to the next, given prevailing traffic patterns, we characterize our rating of *low* as being *uncertain*.

Long-Term Effectiveness in Reducing Congestion

Rating: Low. Triple convergence limits the ability of HOV lanes to relieve congestion in the general-purpose lanes in the longer term. If more travelers form carpools or switch to transit to take advantage of higher speeds in the carpool lanes and, as a result, the general-purpose lanes speed up, travelers will begin to shift from other modes, other times, or other routes to take advantage of the freed capacity. This will slowly erode any congestion relief in the general-purpose lanes.

Congestion relief in the HOV lanes themselves also appears to face longer-term limits. According to ARB and Caltrans guidelines, the maximum effective capacity of HOV lanes is around 1,650 vehicles per hour. Above this threshold, average travel speeds decrease, congestion begins to build, and the timesaving incentive to carpool is correspondingly diminished (Long, 2000). Many of the HOV lanes in Los Angeles have already reached or are approaching this limit. In one study, 10 out of the 16 L.A. County HOV routes examined were carrying between 1,200 to 1,600 vehicles per hour during the peak commute hours (Parsons Brinckerhoff, 2002). More recently, Caltrans District 7 (2006) reported that HOV facilities in L.A. County carry an average of 1,400 vehicles per hour during the peak travel periods. HOV traffic could be reduced in the short term through some of the strategies enumerated here, such as raising the minimum occupancy criterion, counting only adult passengers and not children, eliminating the clean air-vehicle HOV exemption, or more actively enforcing HOV

violations. Assuming that travel continues to grow at historic rates, however, the lanes will inevitably fill up over the longer term even with these measures in place.

The longer-term limitations of HOV lanes have prompted some states, such as New Jersey, to convert HOV lanes back to general-purpose lanes. Other states, such as Tennessee and Minnesota, have proposed similar conversions (Long, 2000).

Mobility, Accessibility, and Traveler Choice

Rating: Good. HOV lanes operating at or below capacity provide travelers willing to carpool, vanpool, or use transit with a valuable alternative for faster and more reliable travel time. According to one study (Parsons Brinckerhoff, 2002), peak-period carpools in Los Angeles reported saving 43 minutes of travel time per day by using HOV lanes for their morning and evening commutes, and the improved speed and reliability of trips in the HOV lanes clearly played a significant role in mode choice:

- Of the interviewed HOV-lane users in Los Angeles, 79 percent stated that the availability of HOV facilities was an important factor in their decision to carpool.
- Of freeway bus riders, 95 percent reported choosing transit based on the bus's ability to travel more quickly in the HOV lanes.
- Of HOV-lane carpools, 50 percent reported that they previously drove alone in the general-purpose lanes on the same freeway.
- Of carpools, 57 percent stated that travel-time savings was their primary motivation for using the HOV lanes (Parsons Brinckerhoff, 2002).

These factors can affect the percentage of carpools on the freeways. From 1992 to 2006, L.A. County freeways with HOV lanes experienced an increase of 72 percent in the total number of carpools during the morning two-hour peak. Freeways without HOV lanes, however, experienced either flat or decreasing numbers of carpools (Caltrans District 7, 2006).

Throughout the United States, HOV lanes have proven to provide greater mobility, accessibility, and traveler choice. During the peak hour, the first HOV route in New Jersey served 700 buses and more than 30,000 passengers. This route moves more commuters in the peak morning hours than any other HOV route in North America. The Henry G. Shirley Memorial Highway in Virginia carries 2,800 vehicles in the morning peak and provides average travel-time savings of 31 and 36 minutes for the morning and evening commute hours, respectively. In another example, Seattle's transit commute-mode split, due to the highly effective use of the HOV system, has grown to more than 45 percent, one of the highest for a western city. On one HOV lane along SR 520 in Seattle, buses carry more people than all of the adjacent general-purpose lanes combined (Fuh and Obenberger, 2002).

Safety

Rating: Neutral (uncertain). The accident rate for HOV lanes could increase if vehicles frequently weave in and out of the lanes, if the facilities were designed as reversible or contraflow HOV lanes, or if they were developed on the freeway shoulder (Fuh and Obenberger, 2002). In Los Angeles, however, most HOV facilities are designed as concurrent-flow lanes in the median, and the solid striping (or, in some cases, physical barriers) between HOV and general-purpose lanes reduces the amount of cross-weaving. If HOV facilities experience less sudden-stop-and-go conditions, safety outcomes in the lanes could even be improved. We have not, however, encountered data suggesting either a positive or negative correlation between HOV lanes and safety outcomes in L.A. County. We therefore rate HOV strategies as *neutral* with respect to safety and describe this rating as *uncertain*.

Economic Efficiency

Rating: Good (uncertain). HOV lanes can foster greater economic efficiency to the extent that they make better use—in terms of person trips, as opposed to vehicle trips—of lane-mile capacity. From this perspective, many HOV lanes in L.A. County appear to be successful, serving more person trips than adjacent general-purpose lanes. This is especially true for HOV lanes offering significant levels of bus service.

According to one study that attempted to quantify the costs and benefits of HOV investments in Los Angeles, existing HOV facilities have an average payback period of nine years (Parsons Brinckerhoff, 2002).

Given these findings, we rate the economic-efficiency effects of HOV facilities as *good*. It is not clear, however, whether some of the short-term HOV strategies—such as converting general-purpose lanes to HOV lanes or changing the occupancy limits on existing lanes—would yield comparable benefits; more detailed analysis on a case-by-case basis would certainly be merited. For this reason, we also qualify the rating as being *uncertain*.

Environment

Rating: Good. According to one study (Parsons Brinckerhoff, 2002), travel in HOV lanes in Los Angeles generates about half the emissions per passenger-mile that travel in the general-purpose lanes on a freeway does. In addition to improving air quality, the potential oil savings due to carpooling and transit ridership can provide significant environmental benefits as well. A study conducted by the International Energy Agency (IEA, 2005) concluded that measures to increase carpooling, including HOV lanes, represent one of the more promising options for achieving significant reductions in oil consumption.

Equity

Rating: Very good. HOV lanes provide travel-time benefits to carpoolers, vanpoolers, and transit users. Because the commute share for these alternatives to single-occupant driving is consistently higher among racial and ethnic minority groups, recent immigrants, and lower-income workers (Pisarski, 2006), HOV lanes support positive equity outcomes. In a recent survey, it was estimated that approximately 88 percent of L.A. County residents supported freeway HOV lanes. A strong level of support was present among all ethnic and income groups, with the highest support expressed by minority ethnicities, lower-income households, and (not surprisingly) current carpool-lane users (Parsons Brinckerhoff, 2002).

Stakeholder Concerns

Rating: Medium/can partially address—>low. The construction of new HOV lanes is not likely to create specific stakeholder opposition. While many environmental groups oppose adding new capacity to California’s state highway system, for instance, the addition of HOV lanes is more commonly considered an acceptable measure to reduce emissions (Long, 2000). Transit organizations should also favor HOV lanes because they allow for faster transit times and thereby encourage greater transit ridership (Parsons Brinckerhoff, 2002).

That said, building new HOV lanes falls beyond the short-term scope of this study. Instead, we consider shorter-term options, such as changing the passenger limit from HOV 2+ to HOV 3+ where existing lanes are already congested in the peak hours. This would raise obvious concerns among two-person carpools currently using the lanes. It may be possible to overcome such concerns if it can be shown that changing the passenger limit would result in greater overall passenger throughput in the corridor; this would require detailed analysis on a case-by-case basis.

General Political Obstacles

Rating: Medium/difficult to address—>medium. The 1998 conversion of HOV lanes to general-purpose lanes on I-287 and I-80 in New Jersey led some to speculate that the public opinions and public-agency support for HOV lanes had declined. Others, however, contend that there is not evidence to suggest a nationwide backlash against HOV lanes (Fuh and Obenberger, 2002). In fact, less than 5 percent of all HOV-lane route-miles have been terminated since 1969. California in particular has experienced an upward trend in HOV-lane construction.

Most voters appear to support the construction of new HOV facilities. A survey in Seattle, for example, found that 72 percent of SOV drivers and 95 percent of HOV drivers believed that “HOV lanes are a good idea” (WSDOT, 2001). In L.A. County, as already noted, an estimated 88 percent of residents support HOV lanes, including 70 percent of freeway motorists who do not use the carpool lanes. Moreover, 82 percent of those interviewed supported the continued use of

sales-tax revenues for highway-infrastructure investments, including HOV lanes. This level of support is relatively consistent across different geographical areas in Los Angeles, across users of different freeways, and across different ethnic and income groups (Parsons Brinckerhoff, 2002).

It is less likely, however, that voters would support some of the shorter-term HOV strategies discussed here, such as the conversion of existing general-purpose lanes to HOV lanes or increases in the minimum occupancy requirements. For instance, the 1976 decision to convert a general-purpose lane on the Santa Monica Freeway to an HOV lane was so unpopular that the lane was converted back to a general-purpose lane after just 21 weeks of operation. Following this experience, most agencies across the country—clearly wary of negative public response—have implemented HOV facilities by building new lanes rather than by converting existing lanes (Fuh and Obenberger, 2002). This experience highlights the importance of the public’s perception of adequate level of use to both implement and sustain an HOV facility. In Seattle and Los Angeles, the public strongly supported a commitment to HOV lanes, but they also believed that HOV lanes were not adequately used (Fuh and Obenberger, 2002). In L.A. County, about half the residents believed that HOV lanes were underused (Parsons Brinckerhoff, 2002). In addition to efforts to increase carpooling and transit service on HOV lanes, efforts to raise public awareness of the benefits of more HOV usage should increase public support.

Institutional Obstacles

Rating: Medium/difficult to address—>medium. Decisions about constructing HOV lanes in L.A. County are subject to review by several agencies. Caltrans needs to gain approval from Metro, which serves as the lead agency in the planning, designing, and funding of HOV projects in L.A. County. Significant changes to existing HOV lanes may be subject to review by ARB, FHWA, and EPA (Long, 2000).

Current Status in the L.A. Region

Rating: Significant. Since the reversion of the Santa Monica Freeway HOV lane to general-purpose lane in 1976, the commonly accept-

able practice in Los Angeles and elsewhere has been to develop HOV facilities by adding lanes rather than by converting existing lanes. This makes the development of an HOV network much more costly. As of January 2000, the state of California had spent \$2.3 billion in state and federal transportation funds to construct 925 HOV lane-miles, averaging \$2.5 million per mile (Long, 2000).

About half of the state's HOV lane-miles are in L.A. County. As of 2006, there were 468 lane-miles of HOV facilities in the county, and plans for additional HOV facilities were in progress. Five additional HOV facilities were in the construction phase, eight were in the design phase, and another 12 were in earlier stages of planning. When completed, L.A. County will have more than 700 lane-miles of HOV facilities in place. Certain heavily used facilities, such as the 10 freeway west of downtown Los Angeles and the 101 freeway, do not yet have HOV lanes, nor have arterial HOV lanes been developed.

Metro is charged with planning and overseeing the development of HOV lanes in the county. In 2002, Metro funded an evaluation of the performance of HOV lanes in the county and developed recommendations for improvements (Parsons Brinckerhoff, 2002). Based on the report, L.A. County has since done the following:

- pursued completion of gaps in the HOV system and its connections with adjacent counties to develop a more continuous HOV system
- pursued freeway-to-freeway HOV connectors at strategic locations between intersecting HOV freeway corridors
- implemented transit services, transit stations, park-and-ride lots, and direct-access ramp connections with existing HOV lanes.

HOV projects in L.A. County are funded by local Proposition C funds along with state and federal funds (Caltrans District 7, 2006). In addition to Metro's planning role, multiple agencies are involved in building and operating HOV lanes in L.A. County. Based on FHWA policy, Caltrans must work with Metro in the development of HOV plans, and Caltrans is responsible for maintaining and operating the freeway network, including HOV lanes. The California Highway Patrol

(CHP) enforces the HOV occupancy requirements. SCAG conducts long-range planning activities for the region—including the analysis of HOV lane additions—and operates a regional ride-sharing program (Parsons Brinckerhoff, 2002).

In 2006, all but one of the L.A. County freeway HOV routes exceeded the minimum threshold for effective capacity utilization of 800 vehicles per hour. In most cases, the lanes exceeded this threshold by more than 50 percent, or 1,200 vehicles per hour. Some of these carpool lanes are nearing their maximum effective capacity of 1,650 vehicles per hour (Caltrans District 7, 2006). Although carpool-lane use is highest during peak hours, almost 40 percent of HOV-lane users are traveling during off-peak hours. On many routes, off-peak and weekend use falls in the range of 30 to 50 percent of peak-hour demand, a sufficient level to support the current 24-hour carpool-operation policy (Parsons Brinckerhoff, 2002).

Interaction with Other Strategies

HOV-lane performance is affected by the availability and condition of other facilities and services that support HOV-lane usage, including freeway-based bus-transit lines (see Appendixes B25 and B26) and park-and-ride lots (see Appendix B4). Seattle provides an example of an HOV system that has been successfully integrated with complementary transit strategies. Seattle offers a high volume of bus transit in the HOV lanes and has developed an express bus service into the CBD that relies on dedicated ramps and lane treatments, resulting in a large percentage of trips being bus commutes. Features of Seattle's freeway bus service include in-line stations, bus flyer stops designed with bus ramps and stations adjacent to the shoulders, park-and-ride lots, and bus-only ramps connecting to a bus subway constructed through the center of the CBD. In Seattle, such features have led to a marked increase in the number of transit commuters (Fuh and Obenberger, 2002).

Other useful strategies include increasing the quality and number of park-and-ride lots near entrances of freeways containing HOV lanes, which will help facilitate carpooling opportunities. Because many HOV facilities are single lanes, even minor traffic incidents, such as disabled vehicles, can severely degrade their performance. Providing

prompt incident response and incident-clearing services (see Appendix B10) is therefore also important for maintaining the benefits of HOV lanes. Proper enforcement is another ongoing challenge. Without proper enforcement of HOV occupancy requirements, travel conditions in the HOV lane will suffer, as will public perceptions of HOV-lane effectiveness. To date, effective means of automating HOV-lane enforcement have not emerged. Hence, the presence of enforcement officers is critical.

Although the majority of HOV facilities in L.A. County carry at least 800 vehicles per hour during the peak hours—the minimum volume threshold considered an effective use of the lane capacity—the volume in at least some HOV lanes falls far short of the maximum capacity of 1,650 vehicles per hour. Converting such facilities into HOT lanes (see Appendix B18) could utilize the lane capacity more effectively while generating revenue for the county.

Park-and-Ride Facilities

Park-and-ride facilities provide parking spaces that allow drivers to connect with carpools, vanpools, or transit services for some portion of their journeys. In addition to parking spaces, park-and-ride lots can include a range of amenities, such as security services, bicycle lockers, telephones, restrooms, and even child-care centers. Park-and-ride lots can range from thousands of spaces with numerous amenities, at the more advanced end of the spectrum, to a few designated spaces in a church or shopping-center parking lot at the other end of the scale. Park-and-ride facilities are usually located near freeway on-ramps or adjacent to regional transit or rail service. As of 2000, at least one form of public transportation served all but eight of the 172 official park-and-ride lots in the SCAG region (LDA Consulting, 2003).

Park-and-ride lots can be found throughout Europe, Asia, and the United States. In the United States, they are common in large metropolitan areas, such as Seattle, Portland, Denver, Houston, San Francisco, and Los Angeles. In Denver and Houston, park-and-ride lots hosting more than 1,000 parking spaces are in operation (KJS Associates, 2001). The state of California has close to 400 park-and-ride lots in operation (Nelson\Nygaard Consulting Associates, 2003), and more than 120 of these can be found in L.A. County (CommuteSmart, undated[b]).

Evaluation of Strategy

Cost/Revenue Implications

Rating: Low cost (uncertain). The cost of providing park-and-ride lots can be considerable. Expenses include not just land acquisition and construction costs, but also ongoing maintenance to ensure that the lots remain safe and attractive, thus encouraging ongoing use. On the other hand, park-and-ride lots typically cost less than providing parking spaces in city centers, where land values are higher. Lower-cost options for park-and-ride lots include sharing spaces with other users, such as at shopping centers or churches (LDA Consulting, 2003).

Park-and-ride lots can also generate revenue by charging drivers for use of the spaces. One survey of park-and-ride users indicated a willingness to pay fees for improved security features, such as security attendants, local police presence, and telephones. Some respondents also indicated a willingness to pay for added bus service, better lighting, and refreshment vendors (Nelson\Nygaard Consulting Associates, 2003). Depending on whether a facility is constructed from scratch or shares existing parking with other establishments and whether usage fees are charged, the net cost/revenue implications can vary considerably. We have selected a rating of *low cost* but note that this rating is *uncertain* and depends on specific circumstances.

Short-Term Effectiveness in Reducing Congestion

Rating: Low (uncertain). The effectiveness of park-and-ride lots in reducing congestion is subject to debate. On one hand, if the provision of park-and-ride lots encourages SOV drivers to give up their vehicles in favor of carpools, vanpools, or transit, traffic and VMT may be reduced. On the other hand, if the lots encourage travelers who formerly relied exclusively on alternative means of transport, such as transit or biking, to form carpools instead, some of these gains may be offset.

Some before-and-after studies have demonstrated that park-and-ride facilities in concert with improved transit services can reduce aggregate VMT in a region. In one study of the initial operating phases of the San Bernardino Transitway and its park-and-ride lots, researchers

estimated that these facilities led to a daily savings of 100,000 VMT (Turnbull et al., 2004). According to another study, the opening of the Philadelphia-Lindenwold High Speed Line and park-and-ride facilities resulted in a 3-percent reduction in traffic volumes (Turnbull et al., 2004).

In a study of England's bus-based park-and-ride lots, 47 percent of the users reported that they would have driven to the city center if the lots were not available, and these users saved an average of 2 km of solo driving per trip (W. S. Atkins Planning Consultants, 1998). Critics of this study, however, have argued that the park-and-ride lots encouraged the other 53 percent of the users to drive to the lots, whereas, in the past, they may have used the bus, biked, walked, or not made the trip at all (Lucas-Smith, 2000). Other studies of bus-based park-and-ride lots in Oxford and York found that some users had switched from non-automotive modes in order to drive to the lot, while others had made additional trips based on the opportunity to park and ride (Parkhurst, 1995). Hence, while highway traffic leading into the urban center may have been reduced, traffic in the immediate vicinity of the park-and-ride lots may have increased.

In addition to encouraging transit use, park-and-ride lots are also intended to encourage carpool and vanpool formation. In a study of park-and-ride users in Dallas, 21 percent expressed that they would not carpool if the park-and-ride lots were not available, while 62 percent indicated that the lot was one of the many factors that led them to carpool. Another study of 150 such lots showed that 60 percent of the users were SOV drivers prior to carpooling, while 35 percent were carpoolers prior to using the lot (LDA Consulting, 2003).

Long-Term Effectiveness in Reducing Congestion

Rating: Low. Though park-and-ride lots may initially enable the formation of carpools or vanpools or greater use of transit facilities, their longer-term effectiveness for reducing congestion is ultimately limited. To begin with, a main incentive for forming carpools or vanpools is the opportunity to save travel time in HOV lanes. Yet as more HOVs use the lanes, the travel-time savings are slowly eroded, thereby discouraging further mode-shift. Second, if park-and-ride lots lead to

increased use of carpools, vanpools, or transit services, and if this, in turn, reduces congestion in the main automotive-travel lanes, the phenomenon of triple convergence will slowly erode the improvements.

To illustrate, a study of Oxford and York park-and-ride lots found no long-term reduction in traffic. In both these cities, the solo-occupant trips removed from the roadways have been replaced over time by new car trips, and, as a result, the original level of congestion has persisted (Parkhurst, 1995). It has also been suggested that, unless parking spaces are removed from the destination centers at the rate at which park-and-ride spaces are created, traffic congestion will most likely continue to rise (Lucas-Smith, 2000).

Mobility, Accessibility, and Traveler Choice

Rating: Good. Park-and-ride lots, when combined with HOV lanes or high-quality transit routes, increase travelers' ability to rely on carpools, vanpools, or transit for at least some portion of their journeys (LDA Consulting, 2003). This has positive effects in terms of mobility, accessibility, and traveler choice. Depending on the specific context, park-and-ride lots may enable travelers to save time (by using an HOV lane or a high-speed transit line) and save money (such as the cost of gas and higher parking prices in downtown locations). They are especially valuable for individuals who do not live near transit lines and would like to save the cost of driving and parking at their final destination.

Safety

Rating: Bad/can partially mitigate—>neutral. The safety issues associated with park-and-ride lots are similar to those for any other type of parking lot. Users desire personal safety and security for their cars while unattended. In a survey of park-and-ride lot users in various Caltrans administrative districts (Nelson\Nygaard Consulting Associates, 2003), respondents reported unsafe conditions as the second-highest priority for improvement. Specifically, users wanted the lots to be well lit and to provide a secure waiting area for the bus or train in the evening hours. In District 7, which includes L.A. County, the top three requested improvements included security attendants (25 percent), local police presence (16 percent), and better lighting (12 per-

cent). The top three improvements that users reported a willingness to pay for included emergency-phone availability (45 percent), local police presence (30 percent), and security attendants (29 percent). The survey also found, not surprisingly, that higher rates of theft and vandalism have had a negative impact on the use of lots. The issue of safety is especially salient in L.A. County, where many of the freeway on-ramps—a convenient location for park-and-ride lots—are located in high-crime neighborhoods. These concerns can be mitigated through some of the security improvements requested by survey participants, but this increases the costs associated with park-and-ride lots.

Economic Efficiency

Rating: Good. Park-and-ride lots can improve economic efficiency by facilitating the use of higher-occupancy modes, such as carpools, vanpools, and transit lines, thereby enabling the existing transportation infrastructure to serve more person trips. In addition, they allow more visitors to travel to a crowded CBD without needing to drive in congested conditions or pay high parking fees. Attracting more visitors to the CBD without a proportional increase in automotive traffic can stimulate greater economic activity without adding to already-congested conditions. Furthermore, it is conceivable that parking spaces in the CBD could gradually be removed and replaced with park-and-ride-lot spaces outside the CBD. Such a trade renders valuable land in the CBD available for more economically beneficial developments that may further attract visitors (Parkhurst, 1995).

Environment

Rating: Good (uncertain). Reducing VMT should generally lead to lower fuel consumption and emissions. Although park-and-ride facilities, by fostering mode-shift from solo driving to higher-occupancy alternatives, may lower VMT, the science of combustion-engine emissions complicates the environmental performance of park-and-ride lots. First, combustion-engine emissions are most severe during the first few minutes of operation, when the engine is cold, generating extra pollution during the first several miles of travel. Second, evaporative emissions continue to be released after the vehicle has been turned off while

the engine is still hot. Due to these two factors, the total emissions for short trips to park-and-ride lots may be only slightly less than for medium-length auto trips directly to the destination (Turnbull et al., 2004).

Park-and-ride lots also may encourage travelers to drive to the transit connection point, whereas they may have used transit, walked, or biked prior to the construction of the lot. In some cases, park-and-ride lots may actually induce new trips that would not have been taken without the convenience of being able to park and ride (Parkhurst, 1995). Furthermore, concern has been raised that park-and-ride facilities conflict with the goals of transit-oriented development—specifically, that they may encourage urban sprawl by lowering the cost and stress of long-distance commutes (Turnbull et al., 2004).

In general, though, well-conceived park-and-ride facilities tend to have a positive environmental impact. It has been estimated, for example, that the opening of the San Bernardino Transitway and its park-and-ride facilities in the 1970s has saved 7 to 10 percent in fuel consumption and reduced emissions by 10 to 20 percent. An analysis of six park-and-ride facilities in the Dallas–Fort Worth area compared the fuel-consumption savings to the energy cost of the facilities. Fuel savings ranged from 50,000 to 200,000 gallons annually, and the construction-energy payback ranged from one to six years (Turnbull et al., 2004). In another report, produced by the International Energy Agency (2005), carpooling was given the highest rating as a means for reducing oil consumption. For these reasons, we have rated the environmental effects of park-and-ride facilities as *good*. Given the concerns outlined here, however, which may vary with contextual factors, we also describe this rating as *uncertain*.

Equity

Rating: Bad/difficult to mitigate—>bad. Since lower-income and racial and ethnic minority travelers tend to rely more on carpooling and transit than others do (Pisarski, 2006), one might expect park-and-ride lots to have positive equity effects. It appears, however, that the benefits of park-and-ride lots accrue more to middle- and upper-income travelers. Lower-income users are less likely, for example, to

receive employer benefits as an incentive for carpooling or using transit from a park-and-ride lot (Deakin et al., 2006). Also, lower-income and other underrepresented travelers may be more likely to carpool or use transit for an entire journey rather than switching modes at a park-and-ride lot. The negative effects of park-and-ride lots, on the other hand, may be more concentrated in lower-income communities. As noted earlier, most Caltrans park-and-ride lots are located either at or near the freeways, and the neighborhoods near the freeways in District 7 tend to be among the lowest-income areas in the county (Nelson\Nygaard Consulting Associates, 2003). As a result, the poorer residents in these areas may experience more traffic entering their neighborhoods to access the park-and-ride lots, resulting in greater exposure to noise and air pollution.

Stakeholder Concerns

Rating: Medium/can partially address—>low. Certain communities may oppose the construction of park-and-ride lots in their neighborhood because they add traffic to their local streets. Residents also may fear that park-and-ride lots will attract individuals who would engage in theft or vandalism in those lots. The latter concern can be partially mitigated with strategies to deter crime, such as police patrols, security guards, surveillance cameras, and proper lighting.

General Political Obstacles

Rating: Low. Certain neighborhoods, as noted, may view freeway-adjacent park-and-ride lots as locally undesirable facilities; other critics may argue that park-and-ride lots attached to public-transit systems help to enable sprawling development patterns. In general, however, the level of political opposition to park-and-ride lots should be low, as they support the ability of many SOV drivers to switch to higher-occupancy modes, such as carpools, vanpools, or transit.

Institutional Obstacles

Rating: Low. While some institutional cooperation may be required in the development of park-and-ride facilities, the obstacles should not be difficult to overcome. For freeway-based park-and-ride

lots, it may be necessary for local, regional, and state transportation agencies to work together in planning and developing the facilities. Local law enforcement may also be enlisted to help improve security at the lots. For park-and-ride facilities attached to transit systems, local transportation agencies and transit-system operators may need to cooperate.

Current Status in the L.A. Region

Rating: Moderate. As noted earlier, there are already more than 120 park-and-ride lots in L.A. County, including facilities owned and operated by such agencies as Caltrans, Metro, and LADOT. Despite the large number of existing facilities, however, there are many opportunities for both expansion and improvement. For example, Nelson\Nygaard Consulting Associates (2003) examined 38 of the 58 lots operated by Caltrans in District 7, finding the following:

- Only eight lots had adequate signage and security.
- Only seven of the lots had on-site personnel.
- Only 13 of the lots included accessible express bus stops.
- Many of the lots, especially those along the 10, 105, and 110 freeways were located in high-crime neighborhoods and thus required additional security efforts.

Each of these findings suggests opportunities for improving existing park-and-ride lots. The same study also identified freeways that appear to be underserved by the current system of park-and-ride lots. Specific suggestions for areas of expansion included the following:

- the I-5 freeway in Santa Clarita, a high-growth area without park-and-ride lots
- the I-10 freeway in Santa Monica and West Los Angeles, for which there are only two small lots, both at a high level of utilization
- the I-405 freeway in the South Bay area and West Los Angeles, very dense areas with too few park-and-ride lots
- the I-605 freeway, which has an HOV lane but no park-and-ride lots

- the I-710 freeway, which has only one park-and-ride facility
- the US-101 in the San Fernando Valley, a high-growth area with an insufficient number of park-and-ride lots
- the SR-60 freeway from East San Gabriel Valley to the county line, which has an insufficient number of lots
- the SR-91 freeway in Cerritos, which has no park-and-ride lots.

According to a more recent review of the HOV system in Los Angeles (Caltrans District 7, 2006), many of these gaps in park-and-ride service have yet to be filled. There also may be room for expanding the availability of park-and-ride lots for transit services. Both Metro (2008) and LADOT (undated[a]) operate such facilities for many of their express bus and rail services, but coverage is not uniform. For example, LADOT operates 14 commuter express lines. No park-and-ride lot serves four of these lines—the 413, 422, 431, and 437—while the other 10 lines offer a total of 32 available lots.

As a final note, while conducting the research for this book, we found that the available information on park-and-ride lots on the Web sites of several local agencies was either insufficient or incorrect. To foster greater utilization of available facilities, it would be helpful for agencies to provide accurate and up-to-date information on the location of lots, the cost (if any) for using the lots, the hours of operation, the level of security offered, and the availability of any other amenities, such as restrooms or refreshments.

Interaction with Other Strategies

Park-and-ride lots by themselves are unlikely to reduce congestion. Rather, they must be integrated with other facilities and services that directly support higher-occupancy transportations, such as HOV lanes (see Appendix B3) or high-quality transit options (see Appendixes B25 and B26). Their performance can be further enhanced through additional strategies that encourage travelers to carpool (see Appendix B11) or use transit rather than driving alone, including employer-based TDM programs (see Appendix B14), employer parking cash-out (see Appendix B21), variable curbside parking rates (see Appendix B20), HOT lanes (see Appendix B18), and cordon congestion tolls (see Appendix B19).

Officers at Intersections

Traffic officers are often used to streamline the flow of traffic through busy intersections before and after special events or when traffic signals are impaired. This same strategy can be extended to reduce traffic congestion on a daily basis by placing traffic officers to help control the busiest intersections during rush hours. Traffic officers at these intersections can actively manage traffic, deter vehicles or pedestrians from blocking intersections, and discourage any other driving behavior that may directly or indirectly exacerbate congestion.

This strategy is currently employed in many cities and states throughout the United States. Examples include Washington, D.C., Atlanta, Toledo, Houston, and Seattle. The strategy was also recently implemented in the city of Los Angeles (L.A. Office of the Mayor, 2005).

Evaluation of Strategy

Cost/Revenue Implications

Rating: Medium cost. This strategy entails significant ongoing operational costs in the form of traffic-officer salaries. If officers are diverted from other duties to control intersections (that is, if additional officers are not hired to staff this function), then there is still a corresponding opportunity cost stemming from the strain on resources to perform other duties—such as patrolling or responding to calls—that the officers could be performing if they were not assigned to traffic control.

Short-Term Effectiveness in Reducing Congestion

Rating: Medium. Existing evidence suggests that this strategy is a relatively effective short-term measure for reducing congestion. A pilot study conducted by the City of Los Angeles found that, by placing officers at some of the city's busiest intersections, the travel times along a series of routes that passed through those intersections were reduced by an average of 31 percent. At one of the busiest intersections, the amount of time spent waiting to pass through the intersection was reduced by 70 percent (Jeff, 2006b).

Inappropriate or illegal driver or pedestrian behavior can exacerbate congestion at busy intersections. Drivers and pedestrians often block the intersection and impede the flow of cross traffic. One study indicates that the presence of traffic officers may deter such behaviors (Pigman, Agent, and Green, 2006). The study tested various techniques and procedures to reduce speed in work zones and found that the presence of traffic officers was most effective in reducing drivers' speed. Likewise, the presence of traffic officers may reduce congestion by deterring drivers from entering the intersection square when they cannot pass all the way through.

Long-Term Effectiveness in Reducing Congestion

Rating: Low. While placing officers at busy intersections can help relieve current traffic conditions, it will do little to stem future system-wide growth in travel and congestion. In addition, triple convergence is likely to erode, over time, any short-term congestion relief.

Mobility, Accessibility, and Traveler Choice

Rating: Good. Using officers to help control busy intersections can improve the traffic flow and, in turn, reduce congestion for drivers as well as bus riders. In addition, it may also help make intersections safer for pedestrians and cyclists.

Safety

Rating: Good. The presence of traffic officers at intersections should have the effect of deterring dangerous driving, cycling, and pedestrian behaviors. Pedestrians are more likely to obey signal rules

and cross only at intersections, while drivers and cyclists are more likely to obey red lights and left-turning rules. Drivers should also be much less likely to act on bouts of road rage. These safer behaviors, collectively, should lead to fewer collisions and fewer acts of aggression (L.A. Office of the Mayor, 2005).

Economic Efficiency

Rating: Good. This strategy should promote greater economic efficiency by facilitating improved traffic flow along the existing arterial road system. To support the claim of economic efficiency, of course, the benefits should exceed the costs. Results from the pilot program conducted by the City of Los Angeles indicated that, for every dollar invested in the deployment of traffic officers, the public received \$4 in travel-time savings, so this would appear to be the case (L.A. Office of the Mayor, 2005).

Environment

Rating: Neutral. This strategy, when effective, reduces delays at intersections. This means that cars should spend less time idling, resulting in greater fuel efficiency along with reduced criteria pollutants and greenhouse-gas emissions. On the other hand, if placing officers at busy intersections improves the system's effective capacity, then more drivers may choose to travel during the busiest periods, likely offsetting the initial emission-reduction gains. For this reason, the strategy is rated as *neutral* with respect to environmental outcomes.

Equity

Rating: Neutral. This strategy should confer benefits equally across all users of the arterial system, including drivers and bus riders.

Stakeholder Concerns

Rating: Low. Law-enforcement agencies, as well as some neighborhood groups, may object if law-enforcement personnel are diverted from other activities, such as patrolling and responding to calls, in order to control intersections. In comparison to many other traffic-

reduction strategies, however, stakeholder concerns are likely to be relatively minor.

General Political Obstacles

Rating: Low. Political obstacles should be low as well. If this strategy is implemented effectively, travel-time reductions along the arterial system should be immediately evident, thus boosting public support. In addition, people generally feel safer when law enforcement is visible. Participants of focus groups expressed that the presence of police and highway patrol made the roads safer by monitoring speeding and erratic driving. Also, they noted the benefits of having officers available in case of emergencies, such as breakdowns, flat tires, or medical emergencies (Downing, 2003). Finally, the strategy of employing traffic officers at intersections to reduce delays does not raise the privacy issues associated with, for example, placing cameras at intersections.

Institutional Obstacles

Rating: Low. Placing officers to help control traffic at busy intersections may require coordination between a municipality's police and transportation departments; both, however, report to the same mayor and city-council members, so the institutional obstacles should be relatively low.

Current Status in the L.A. Region

Rating: Significant. The City of Los Angeles recently conducted a pilot program of placing traffic officers at key intersections. Fifty traffic officers were deployed to 40 key intersections for seven months. A comparison of travel times before and during the pilot showed an average decrease in travel times along a series of routes passing through the controlled intersections of 31 percent (Jeff, 2006b).

Since the pilot period, the City has continued to deploy traffic officers at 51 of its most congested intersections. The City is also conducting ongoing surveys for possible new locations at which to employ this strategy. The Bureau of Parking Enforcement and Traffic Control is responsible for deploying traffic officers (Price, 2007).

Additional opportunities that the City could pursue include using camera and communication technology to better inform officers of relevant road and traffic conditions to assist in their efforts to direct traffic as efficiently as possible. This practice has been implemented in Washington, D.C., where cameras at intersections send visual data to traffic-control rooms. Operators in these control rooms then communicate relevant information to the officers assigned to the relevant intersections (Tuss, 2007). Providing officers at intersections with manual control of traffic signals is also worth considering. A study showed that manual operation improved the flow at congested signalized intersections better than automatic, programmed traffic-signal operation, as measured by the degree of congestion and total throughput (Mahalel, Gur, and Shiftan, 1991).

Interaction with Other Strategies

This strategy should complement efforts to improve bus transit services (see Appendixes B25 and B26), since buses as well as private automobiles will enjoy reduced travel times along the arterial system. In addition, traffic officers could prioritize the right-of-way for buses, thereby further improving bus travel time.

Note that, if officers are deployed to intersections involving free-way on-ramps, ramp meters may, at times, limit their effectiveness (see Appendix B1), in the sense that the ramp-metering system constrains the rate at which traffic officers can direct traffic onto the on-ramp.

This strategy can also work cooperatively with parking enforcement and cameras at intersections. Washington, D.C., is an example of such cooperation. When not directing traffic, the traffic officers are tasked to enforce parking regulations that have the most impact on downtown traffic, such as double-parking and parking at loading and unloading zones (DDOT, 2004; MPDC, 1998). The program also works in conjunction with intersection cameras. The cameras do not record but can zoom in enough to read license plates. As of June 2007, the district had 150 traffic cameras with plans to add another 100 over the next two years. The cameras are used to inform traffic-control officers at intersections which routes are clogged and which roads are free, helping them to better direct traffic (Tuss, 2007).

Left-Turn Signals

Left-turning traffic can be a significant source of congestion. At busy intersections, motorists wanting to make a left turn may have to wait until the yellow light if the opposing through traffic never provides a gap sufficient to execute the turn safely. Meanwhile, traffic builds up behind the left-turning car, creating delay and congestion. A recent study of key intersections in Los Angeles demonstrated the effect of left-turning traffic on congestion. In about one-third of the intersections studied, left-turning traffic contributed significantly to the level of congestion (Jeff, 2006b).

To alleviate such situations, one strategy is simply to prohibit left turns, either at all times or during peak travel periods only. This strategy, commonly employed at busy intersections, can be effective in reducing intersection delays but also makes it more difficult for travelers to navigate through an area. Another alternative is to construct separate left-turn lanes so that left-turning traffic does not impede the flow of through traffic. (Note, however, that if a left-turn lane reaches full capacity, any additional left-turning traffic will overflow onto the main traffic lane and impede traffic flow.)

This strategy analysis focuses on the use of left-turn signals (rather than left-turn prohibitions), including consideration of alternative signal-timing protocols that may be employed with left-turn lanes. To alleviate congestion due to left-turning traffic, various left-turning protocols have been implemented throughout the United States. The main options include the following:

- *Permissive (or unprotected)*: There is no protected phase for left-turning traffic. To turn left, motorists must use gaps in oncoming traffic while the traffic light is green or has just turned yellow.
- *Protected (or exclusive)*: An exclusive phase for left-turning traffic occurs when the green arrow is displayed, usually followed by a yellow arrow. At the end of the yellow arrow, through traffic is given the standard (round) green light, and the left-turning lane is given a red arrow, prohibiting left turns during gaps in oncoming traffic.
- *Protected/permissive (or leading)*: Left-turning traffic is first given an exclusive phase (a green left arrow followed by a yellow arrow). Once the exclusive phase has ended, left-turning traffic faces a green circle (as opposed to a red arrow) and may turn left during gaps in the oncoming traffic. The two phases occur within the same signal cycle, with the protected phase leading the permissive phase.
- *Permissive/protected (or lagging)*: In this protocol, the permissive-left-turn phase occurs first, followed by the exclusive-left-turn phase. In other words, the protected phase lags the permissive one (Hauer, 2004).

While protected left turns are safer than permissive left turns, the protected-left-turn phase does result in delays for the left-turning traffic flow. Protected/permissive and permissive/protected left-turn phasing (leading PPLT and lagging PPLT, respectively), in contrast, are designed to minimize the delay by eliminating the need for the red arrow and allowing vehicles to turn on the green circle whenever possible. Without the red arrow, motorists do not have to wait to turn left when there is no opposing traffic, a situation that often occurs during periods of low traffic volumes. However, the protected phase of the signal timing still provides a green left-turn arrow when left-turning traffic is heavy (Noyce, Fambro, and Kacir, 2000).

In various cities in the United States, there are significant variations in the display and configuration of PPLT signals for left turns. The FHWA (2003a) *Manual on Uniform Traffic Control Devices* (MUTCD) allows the use of several PPLT signal-display arrangements that include

five lights (typically green and yellow arrows and green, yellow, and red circles). The five lights are commonly arranged horizontally, vertically, or in a clustered pattern (two on top, three on the bottom or vice versa). The MUTCD also states that a green-arrow indication shall be used with the protected-left-turn phase and a green-circle indication with the permissive-left-turn phase. However, some traffic engineers argue that the green-circle permissive indication can be misinterpreted as a protected indication, creating a potential safety problem. To improve driver understanding and safety, at least four variations of the PPLT permissive indication have been developed: a flashing red circle, a flashing yellow circle, a flashing red arrow, and a flashing yellow arrow. The variability in permissive-signal indication, signal-display arrangement, signal-display placement, and the use of supplemental signs has led to numerous PPLT signal displays throughout the United States (Noyce, Fambro, and Kacir, 2000).

To characterize this variation, Noyce, Kacir, et al. (1999), provided the results of a survey examining the use of PPLT signal controls in the United States.¹ Of the agencies responding to the survey, 29 percent used some form of PPLT signal control. In terms of signal design, the five-light clustered arrangement was the most common, used in about 63 percent of the reported cases, while 98 percent of the responding agencies used a green circle during the permissive-left-turn phase. In addition, about half of the agencies indicated that they always used a supplemental sign, such as “Left Turn Yield on Green,” with the PPLT signal. With respect to signal sequencing, 83 percent of the reported PPLT signalized intersections used a leading left-turn sequence, while another 11 percent employed a lagging sequence. The final 6 percent used a combined lead/lag sequence.

¹ Noyce, Kacir, et al. (1999), estimated that there are 300,000 signalized intersections in the United States. Of these, their survey covered more than 107,000 from all 50 states.

Evaluation of Strategy

Cost/Revenue Implications

Rating: Medium cost (uncertain). Depending on which specific left-turn phasing strategy is implemented, the range in cost can vary widely. If the implementation is as simple as repainting the lane lines to designate a left-turn lane for permissive phasing, the cost is relatively low. On the other hand, actuated signals that intelligently change between leading and lagging PPLT phasing could require installation of new signal displays, supplemental signage, sensors or loop detectors, traffic cameras, and support personnel. Installation of such advanced technology throughout a region would require significant installation, operational, and maintenance costs. Given the variability in potential costs, we assess the strategy as having *medium cost* implications, but we also describe this rating as being *uncertain*.

Short-Term Effectiveness in Reducing Congestion

Rating: Medium. There is significant evidence to suggest that the implementation of left-turn lanes and signalization can produce substantial reductions in congestion on the arterial system, though certain timing strategies are more effective than others. One study, for instance, employed simulation to investigate what impact the presence or absence of left-turn signals had on congestion. The study examined four types of left-turn strategies: (1) adding a left-turn lane with a protected-left-turn phase, (2) adding a left-turn lane with a permissive-left-turn phase, (3) adding an additional lane in each direction along with a left-turn lane with a protected-left-turn phase at every intersection, and (4) adding an additional lane in each direction along with a left-turn lane with a permissive-left-turn phase at every intersection. Note that strategies 1 and 3 included left-turn signals (a green arrow), while strategies 2 and 4 did not (rather, they just used the standard green circle). The study authors found that each strategy, when compared with the base case of no improvements, offered significant positive effects in reducing congestion and air pollution. However, the fourth strategy (4) was the best alternative in most cases, and the permissive-left-turn phasing in strategies 2 and 4 was better at reducing congestion

than the protected phasing in strategies 1 and 3 in the majority of the cases (Kusuma, 1999).

Consistent with the aforementioned study, field studies comparing traffic delays for permissive and protected phasing protocols also suggest that permissive phasing results in less overall delay. In one study that examined three signals that were changed from permissive to protected phasing, for example, traffic delays at the intersections increased about fivefold. Another study showed that, when protected phasing was replaced with permissive phasing, there was a reduction in left-turn delays of about 50 percent, a reduction in opposing-traffic delay of about 10 percent, and a reduction in total intersection delay of about 24 percent (Hauer, 2004).

PPLT timing protocols, which contain both permissive and protected phases, also appear to offer greater delay reductions than does protected timing alone. In one study, when a signal's protected phasing was changed to PPLT phasing, the alteration resulted in a 40-percent reduction in left-turn delay and a 24-percent reduction in oncoming through delay. In a second case, an intersection's left-turn phasing was initially changed from protected to protected/permissive (leading), then subsequently changed to permissive/protected (lagging). The leading protocol produced the least delay, followed by the lagging protocol, while the protected phasing resulted in the greatest delay. This pattern held for both left-turn and through-traffic delay. Another study measured the delay for left-turning motorists for permissive, protected (leading and lagging), and PPLT (leading and lagging) protocols. Permissive phasing had the shortest delay, followed by leading PPLT, lagging PPLT, lagging protected, and leading protected (Hauer, 2004).

Other studies have examined the differences between leading and lagging arrows for protected left turns, and here the results are less conclusive. Until the early 1980s, the City of Tucson relied exclusively on leading left-turn arrows. In 1984, the city experimented with lagging-left-turn signal phasing at one intersection. Before-and-after studies comparing the two methods showed that, during much of the day, lagging phasing was superior, leading to improved traffic progression, reduced delay, and fewer traffic accidents (CTDOT, undated). A separate study by Li, Wang, and Han (2002) produced similar results,

finding that a lagging cycle for protected turns was better than a leading cycle at reducing congestion delay at isolated, fixed-time intersections. In contrast, field studies conducted in the Phoenix and Tucson metropolitan areas resulted in a different conclusion (J. Lee et al., 1993). When comparing leading- and lagging-left-turn signal phasing at isolated, traffic-actuated intersection signals in both areas, total intersection delay was significantly greater with the lagging-left-turn operation.

Based on these studies, it is difficult to conclude whether leading or lagging phasing is superior. The results appear to depend on other variables, such as whether the signals are fixed-time or traffic-actuated, as well as the left-turn phasing for cross-traffic at the intersection. It is likely that other factors, such as average traffic speed, average traffic volume, and the number of oncoming lanes, will also affect the relative performance of leading and lagging phasing. Considering this ambiguity, it is perhaps surprising that 83 percent of PPLT signals are structured with a leading signal phasing for the protected-turn component, as indicated in the survey reported by Noyce, Kacir, et al. (1999).

Whereas these studies focus on isolated left-turn intersections, Li, Wang, and Han (2002) studied the traffic-flow patterns at two coordinated signalized intersections, comparing the differences in delay based on leading and lagging signal phase combinations. The simulation study found no difference between leading and lagging phasing in delays for through traffic at the coordinated intersections. There were, however, differences in the level of delays for left-turning traffic. Specifically, the use of lagging phasing for the downstream signal resulted in less delay than the use of leading phasing, regardless of the protocol employed for the upstream signal. Using lagging signal phasing at both intersections yielded the best results in terms of overall intersection delays for turning traffic.

Another study was conducted to examine how alternative PPLT display arrangements (including three-, four-, and five-light configurations as well as horizontal, vertical, and clustered light alignments), alternative permissive turn indicators (including different combinations of green, yellow, and red lights, round versus arrow-shaped lights, and flashing versus solid lights), and alternative signal-phasing protocols

(leading versus lagging) combined to affect left-turning capacity and delay (Brehmer et al., 2003). Eight field locations were chosen for the study: College Station and Dallas, Texas; Orlando, Florida; Portland, Oregon; Cupertino, California; Dover, Delaware; Oakland County, Michigan; and Seattle, Washington. At 26 intersections dispersed throughout the eight locations, researchers collected data on the saturation flow rate, lost start-up time, response time, and follow-up headway data in order to measure capacity and delay.² Based on the results of the study, the researchers concluded that the type of signal-display arrangement, the type of permissive turn indicator, and phasing for the permissive turning cycle had little effect on the saturation flow rate for either left-turning traffic or through traffic. On the other hand, the lagging-left-turn signal phasing appeared to result in lower lost start-up times and response times than the leading-left-turn signal phasing, a finding that the researchers attributed to drivers' ability to better anticipate the onset of the protected-left-turn phase during a lagging phasing protocol. The five-section cluster display using a green circle to indicate the permissive-left-turn cycle was associated with the shortest average follow-up headway time. In contrast, the four-section cluster display using a flashing red arrow to indicate permissive left turns had the longest average follow-up headway time, since drivers are required to stop before turning left with a flashing red permitted indication.

As the preceding discussion suggests, determining which signal phasing produces the least delay is a complex issue. The best choice for a particular intersection likely depends on a range of context-specific variables, such as oncoming traffic speed, the number of oncoming traffic lanes, the volume of traffic, and the use of timed versus traffic-actuated signals. That said, some general trends do appear. Specifically, permissive-left-turn timing protocols appear to offer the most significant reductions in delay, followed by PPLT, followed by protected phasing.

² Saturation flow rate is the maximum flow that can pass through a given lane group. Lost start-up time consists of the time to recognize the change in signal indication. Response time is the time to react to change in signal indication. Follow-up headway is the time between the departure of a permissive-left-turn vehicle and the departure of the next vehicle using the same gap in oncoming traffic (Brehmer et al., 2003).

Long-Term Effectiveness in Reducing Congestion

Rating: Low. As described, left-turn signal treatments at busy intersections can achieve significant reductions in congestion delay in the short term for both left-turning and through traffic. However, this strategy will do little to stem future systemwide growth in travel and congestion. Moreover, as with most strategies intended to reduce congestion by increasing the efficiency of existing capacity, triple convergence is likely to erode any short-term benefits. For these reasons, the longer-term effectiveness of left-turn signals in reducing traffic is rated as *low*.

Mobility, Accessibility, and Traveler Choice

Rating: Good. By reducing intersection delays, left-turn signals boost the overall capacity of the arterial system. Even if the congestion-reduction benefits degrade over time with the effects of triple convergence, more drivers will still be able to use the system at any given time. Thus net mobility is enhanced.

Safety

Rating: Neutral (uncertain). Depending on the specific left-turn signal timing protocols employed, safety outcomes may either improve or deteriorate. For this reason, we rate the safety effects as *neutral*, though we describe this rating as being *uncertain*. Although exceptions do exist, as a general rule, protected phasing for left turns is the safest option, followed by PPLT phasing, and finally by permissive phasing (Hauer, 2004). Note that this ordering stands in direct conflict with the ability to reduce traffic delays, for which permissive timing is the superior alternative. In other words, available left-turn signal timing strategies present an inherent trade-off between safety outcomes and the reduction of traffic delays.

Asante, Ardekani, and Williams (1993) examined collision rates for permissive, protected, and PPLT intersections in Texas. The study found that intersections with protected signal phasing were the safest, with approximately 146 conflicts (accidents) per million squared vehicles per lane (cpmsvl). Intersections with PPLT signal phasing had a slightly higher average rate of 176 cpmsvl, while intersections with

permissive phasing produced a significantly higher average rate of 914 cpmsvl. Between leading and lagging PPLT phasing, the lagging PPLT sequence resulted in lower conflict rates.

In another study, Benioff and Rorabaugh (1980) examined the before-and-after results for four intersections where protected phasing was changed to leading PPLT. As a result of these changes, the number of left-turn accidents increased by 1,500 percent, while the number of rear-end accidents decreased by 40 percent. At the aggregate level, the rate of accidents increased by about 140 percent.

A study in Indiana compared the safety afforded by leading PPLT and lagging PPLT (Hummer, Montgomery, and Sinha, 1991). Compared to a lagging sequence, the leading sequence was associated with three times as many left-turn/pedestrian conflicts, which occur when a pedestrian or cyclist crosses in front of a vehicle that has the right-of-way, causing the vehicle to brake or swerve to avoid a collision. The leading sequence also had significantly greater rates of collisions between left-turning and oncoming traffic. Drivers often entered the intersection during and after the yellow clearance phase of a leading sequence and created a through-movement conflict. Lagging phasing, however, produced more rear-end collisions related to driver indecision. Such conflicts arise when a left-turning vehicle hesitates when presented with a protected signal, starts and then stops abruptly with a permissive signal, or fails to turn left on the permissive signal when there is no oncoming traffic.

Another study, performed in Scottsdale, Arizona, compared the collision rates at intersections with leading and lagging PPLT operations. The lagging sequence resulted in significantly lower collision rates than the leading sequence for both collisions involving two left-turning vehicles (one behind the other) and those involving a left-turning vehicle and an opposing through-traffic vehicle (Basha, 2007). On the whole, then, though the evidence is not uniform, it appears that the lagging sequence results in better safety outcomes than the leading sequence.

Another concern that can affect safety outcomes is how well drivers understand alternative displays for the permissive left-turn signal. Along these lines, a study by Brehmer et al. (2003) evaluated drivers' understanding of the following permissive-left-turn indications in

a PPLT phasing: a solid green circle, a flashing yellow arrow, a flashing yellow circle, a flashing red arrow, and a flashing red circle. Of these, the green circle appeared to cause the highest level of confusion, as it was understood correctly just 50 percent of the time. The level of understanding improved, in ascending order, with the flashing red arrow (56 percent), the flashing yellow arrow (57 percent), the flashing yellow circle (62 percent), and the flashing red circle (64 percent). Generally speaking, flashing indicators were better understood than solid ones, as measured by accuracy and overall time to respond, while round signals were better understood than arrow indicators. In addition, the study found that the simultaneous display of two indicators (for instance, a green circle for through traffic and a flashing red arrow for left turns) tended to reduce the level of driver understanding. The same study also examined the effectiveness of alternative indicators for protected left turns in PPLT displays. When a green arrow (for protected left turns) and a solid red circle (for prohibited through-traffic movement) were simultaneously presented in five-section PPLT signal displays, the level of driver comprehension dropped significantly for all five-light configurations (vertical, horizontal, and cluster). Placing the green arrow to the right of the solid red circle, as required by the MUTCD, produced the lowest comprehension rate as measured by accuracy and response time. Simultaneous indicators were not used for three- and four-light displays, and these produced the highest level of driver comprehension. The analysis of intersection collisions from eight cities supported these findings.

Economic Efficiency

Rating: Good (uncertain). This strategy should promote greater economic efficiency by facilitating improved traffic flows along the existing arterial road system. On the other hand, if the selected signal-phasing strategy results in more collisions, the costs may exceed the benefits. When evaluating this strategy with respect to economic efficiency, it is therefore important to consider both congestion-reduction and safety outcomes. One study, for instance, examined the effects of converting an intersection from protected to permissive signal phasing, a change that resulted in a 50-percent reduction in left-turn delays but

also increased the rate of collisions. Even with the increased collision rate, an economic analysis of this case estimated the overall benefit (delay reduction) to cost (increase in accidents) ratio as 1.8 to 1 (Hauer, 2004). Based on this evidence, we rate the economic efficiency outcomes as *good*. Given that such results might vary from one instance to the next, however, we also describe this rating as *uncertain*.

Environment

Rating: Neutral. This strategy, when effective, reduces delays at intersections. This means that cars should spend less time idling, resulting in greater fuel efficiency along with reduced criteria pollutants and greenhouse-gas emissions. On the other hand, left-turn signals increase the effective capacity of the system. This allows even more cars to travel during the busiest periods, which will tend to offset the initial emission reductions. For this reason, the strategy is rated as *neutral* with respect to environmental outcomes.

Equity

Rating: Neutral. This strategy should confer benefits equally across all users of the arterial system, including drivers and bus riders.

Stakeholder Concerns

Rating: Low. Given that permissive and PPLT signals reduce delay but at the same time increase the frequency of collisions, stakeholders with a strong interest in traffic safety—such as the insurance industry or law-enforcement agencies—may oppose plans to replace protected signals with either permissive or PPLT signals. That said, when compared with more-controversial strategies, such as congestion tolls, market-rate pricing for curb parking, or mandatory employer trip-reduction programs, the level of stakeholder opposition that might arise from left-turn treatments is likely to be relatively muted.

General Political Obstacles

Rating: Low. Public support is likely to depend on which left-turn phasing is currently present and which phasing is installed as a replacement. Some part of the public will prefer safety to reductions in delay,

while others will prefer the opposite. A significant reduction in congestion without markedly increasing the frequency of accidents will likely earn public support.

Institutional Obstacles

Rating: Low. Most arterial streets fall under the jurisdiction of individual municipalities. This reduces the potential for institutional obstacles because, given available funding and the approval of the mayor and city-council members, municipal DOTs typically can implement changes to the configuration and timing of intersection signals.

Current Status in the L.A. Region

Rating: Significant. Left-turn lanes and signals at arterial intersections are common in metropolitan areas across the country, and Los Angeles is certainly no exception. Yet there are also busy intersections that are not so equipped, suggesting that there may still be room for improvement. For example, as part of its ongoing congestion-relief efforts, LADOT is continuing to add left-turn lanes and left-turn signal arrows to reduce intersection delays.

In March 2006, city officials announced a four-year plan to install 450 left-turn signals at intersections throughout Los Angeles at a cost of approximately \$8 million. At that time, about 1,700 intersections in the city had left-turn arrows, so the plan represented a fairly significant upgrade (“Left-Turn Signals to Be Installed at 450 Intersections,” 2006). By the fall of 2007, LADOT had installed 189, or just over 40 percent, of the planned 450 left-turn arrows (L.A. Office of the Mayor, 2007a). Building on that momentum, in October 2007, the City added 30 new left-turn arrows in a 30-day period as part of its 30/30 initiative. The new signals were placed at some of the busiest intersections in the San Fernando area, on the Westside, and near LAX. LADOT engineers estimated that these improvements would reduce collisions at the intersections by about two-thirds while reducing commute times (L.A. Office of the Mayor, 2007c).

More recently, the mayor’s office announced the installation of 100 left-turn arrows at 45 congested intersections in the city, starting on January 2, 2008, and projected to finish by June 30 (L.A. Office

of the Mayor, 2007c). The program is projected to cost \$3 million. Sixty of the new lights will be installed in the San Fernando Valley. The Westside and central parts of the city will each receive 12 left-turn signals, and South Los Angeles will receive 14 left-turn signals (“Mayor: LA Drivers Have ‘Fundamental Right to Turn Left,’” 2007). It is unclear whether the 450, 100, and 30 left-turn signals are all separate signals or there is a duplication in count (“Caught in a Jam After Taking Mass Transit,” 2007).

Interaction with Other Strategies

Many of the advanced technologies used to support traveler-information systems (see Appendix B15), signal timing and control (see Appendix B2), and incident-management systems (see Appendix B10) can also be used to implement more-sophisticated left-turn-signal strategies. Using vehicle-sensing technology, such as loop detectors, for instance, the protected phase of PPLT can be skipped when left-turning vehicles are not present in the left-turn lane, thereby reducing delays for oncoming through traffic. Furthermore, PPLT phasing can be alternated between a lagging and a leading protocol at an intersection, depending on the current traffic conditions. Such is the current practice in Dallas, Texas (Brehmer et al., 2003).

Using variable-message lane-use control signs, a common feature of traveler-information systems, one or more of the through-movement lanes can be reassigned for left turns during peak-demand hours. The temporary left-turn lanes can then be reverted back to through-movement lanes during low left-turn-demand hours (Wainwright, 2004).

Curb-Parking Restrictions

The term *parking management* refers to a suite of strategies intended to promote more-efficient use of parking resources to foster more-efficient travel patterns. Options include pricing strategies, parking districts, caps on the provision of new parking spaces, park-and-ride lots, the unbundling of parking leases, and restrictions on the allowable time or duration of parking, to name a few (VTPI, 2008d). The strategy discussed here involves restricting on-street parking on certain routes at certain times so as to free up additional lane space for the flow of traffic, essentially reducing the number of available parking spaces to increase street capacity. Other short-term parking-management strategies considered separately in this book include variable curb-parking rates (see Appendix B20) and employer parking cash-out programs (see Appendix B21).

Many cities around the world have adopted a policy of reducing, rather than increasing, the number of available parking spaces as a means of both reducing automotive demand and promoting smoother traffic flows. For instance, Zürich does not have an underground metro like many major European cities. It does, however, have well-developed commuter-rail and bus systems serving the metropolitan area. To improve the efficiency of transit operations, Zürich eliminated on-street parking along the streets with major bus and tram services. In conjunction with transit-service improvements, these strategies helped encourage greater use of public transit, cycling, and walking in Zürich (London Assembly, 2002). Zürich's successful traffic management is

one of the reasons that it was rated first out of 215 cities in a recent worldwide quality-of-life survey (Mercer, 2007).

As part of its efforts to reduce congestion, London adopted a similar strategy by eliminating on-street parking along the “red routes,” a network of 580 km of roads that carry 35 percent of the city’s traffic (TfL, undated). This policy was based on the recognition that parking along the red routes represented a major source of congestion, limiting available lane capacity and causing delays as vehicles entered or exited parking spaces (London Assembly, 2002). Many other cities in the United Kingdom have restricted on-street parking on certain routes during the peak travel periods (Booz Allen Hamilton, 2006). Toronto is another city that does not allow on-street parking during rush hours on selected major arterials (Heffron Transportation, 2002).

Cities in the United States have also implemented on-street-parking restrictions. As early as 1975, Portland set a ceiling for on-street parking in the city center (Booz Allen Hamilton, 2006). New York City has eliminated on-street parking near intersections to provide an unimpeded right-turning lane and reduce bus delays (Schaller Consulting, 2002). In Seattle, on-street parking is not allowed during the morning or evening hours on many corridors. Seattle has explored several variants of this policy, including spot restrictions (e.g., near an intersection only), along just one side of a street in the direction of peak-hour flow, and along both sides of a street. These policies demonstrate that Seattle places greater priority on moving traffic and transit through arterials than providing parking (Heffron Transportation, 2002). The City of Los Angeles has also implemented peak-hour on-street-parking restrictions on major travel corridors, such as Wilshire Boulevard (L.A. Office of the Mayor, undated).

Evaluation of Strategy

Cost/Revenue Implications

Rating: Neutral (uncertain). Restricting parking entails both costs and revenues. To begin with, parking restrictions must be actively enforced if they are to be effective (Flynn et al., 2003). This requires

additional parking-enforcement officers and may increase administrative costs as well. In addition, cities must forgo the revenue that parking meters might have generated along parking-restricted routes. On the other hand, citations for parking violations in the restricted areas create a source of revenue for the city. While we have not encountered any studies offering a direct comparison between the costs and revenues associated with parking-restriction programs, we do have some evidence of the magnitude of parking-citation revenues. The revenue from such citations is significant, quite possibly enough to offset the costs. For this reason, we rank this strategy as *neutral* with respect to cost/revenue implications, though we describe this rating as *uncertain*.

As an illustration of the revenues associated with parking violations, consider the following examples. In the early 1980s, Boston began to target the most flagrant parking violators, those with outstanding parking ticket bills in excess of \$400. The goal was to recoup around \$47.5 million in outstanding parking-violation fines (McShane and Meyer, 1982). More-recent figures indicate that Boston now employs about 150 parking-enforcement officers, issues about 1.7 million parking tickets, and collects around \$55 million in ticket revenue each year. This corresponds to about \$367,000 in annual ticket revenues per enforcement officer. San Francisco, in turn, employs around 260 parking-enforcement officers, issues about 2.2 million tickets, and collects more than \$63 million in revenue each year, or about \$242,000 per officer (Heffron Transportation, 2002).

Because both the costs and revenues associated with parking enforcement are significant, cities have ample incentive to explore ways of pursuing enforcement activities more efficiently. In Massachusetts, the City of Cambridge realigned the beats of its parking-enforcement officers to target the areas with the highest levels of violations, thereby achieving stricter enforcement and enhanced revenues without incurring greater personnel costs (Flynn et al., 2003).

Recent technology developments may also help in the effort to provide more-effective parking management and enforcement at lower costs (FHWA, 2007). For instance, technology now allows for the automated ticketing of parking violators without the need for officers to exit the car (thus avoiding, as an additional benefit, potential alterca-

tions with vehicle owners). One system in this vein uses a video camera and license-plate-recognition algorithm to automatically determine whether a car has been parked longer than the allowed time. As the parking-enforcement officer drives by cars, tickets are automatically issued to violators.

A similar approach has been developed in Seoul, where the city's traffic-control center monitors major arterials via a CCTV network. If a vehicle parks illegally, the cameras record a time-stamped image of the vehicle and its license plate. If, after five minutes, the vehicle has not moved, a second set of images is recorded. The license-plate number is then interpreted using optical character-recognition software, and a parking ticket is sent to the offending motorist. If another 10 minutes passes and the vehicle is still parked illegally, a tow truck is dispatched to remove the vehicle. For a relatively low cost, this system has greatly reduced the traffic delays and accident risks posed by illegally parked vehicles. As an added benefit, there are few challenges against the issued citations, since motorists are provided with pictures showing their illegally parked vehicles (Kielland, 2004).

Short-Term Effectiveness in Reducing Congestion

Rating: Medium. Restricting on-street parking on arterials provides an additional travel lane, boosting capacity and, in turn, reducing congestion. When the City of Los Angeles implemented peak-hour parking restrictions on Ventura Boulevard and enforced the restrictions more aggressively (L.A. Office of the Mayor, 2006), Metro studied how this change affected bus travel speeds for the Rapid 750 line. As the city began to cite and tow illegally parked vehicles more promptly, average travel speeds for buses during the morning rush hour increased by about 2 mph, or roughly 10 percent (Kumar, 2007).

In addition to allowing existing traffic to flow more freely, parking restrictions may reduce the overall number of car trips. The basic logic is that, if plenty of parking spaces are available in an area, more visitors will likely choose to drive (BMA Transportation Services, 2007). As parking becomes more restricted (and typically more expensive as a result), more visitors are likely to carpool or use transit. For this reason,

many cities have found that parking restraints effectively reduce the proportion of SOV trips (EPA, Cambridge, and Comsis, 1992).

A recent report by Booz Allen Hamilton (2006) synthesized the results of several studies examining the relationship between parking and choice of travel mode. In one study, researchers observed that the cities of Portland, San Francisco, Zürich, Berne, and Seattle all employ restrictive on-street-parking policies, and, in each case, the transit mode share is relatively high. Another study examined the effects of instituting central-city parking restrictions in the UK cities of York, Oxford, and Canterbury. In each of these cases, the implementation of parking restrictions led to a higher mode share for public transit. A third study examined five UK cities and compared the likely effects of several alternative policies intended to boost transit use, including reducing the price of transit fares by 50 percent, raising fuel costs by 50 percent, doubling parking charges, applying a cordon toll to the center city, and reducing the supply of parking spaces by 50 percent. The study results suggested that reducing the supply of parking would have the greatest effect, decreasing car use in the central-city areas by about one-third.

Another study examined the effects of implementing a system of residential parking permits in Munich on the modal choices of employees working in the same areas. (Note that, from the perspective of nonresidents, a residential parking-permit system is similar to out-right parking restrictions in the sense that it likewise limits the available stock of parking spaces for nonresidents.) Once the street parking was limited to residents, the share of SOV driving among nonresidents dropped from 44 percent to 32 percent (Topp, 1991).

In short, curbside-parking restrictions both enhance an arterial street's lane capacity and encourage more travelers to use transit or other alternative modes. Note, however, that the degree to which restricting parking will reduce the number of trips to an area depends, at least in part, on the characteristics of the parking spaces being eliminated. For example, a parking space with an all-day time limit might restrict traffic in that space to only one vehicle trip per day, while a parking space with a one-hour time limit might allow 10 trips each day (Topp, 1991). Regardless, reducing the supply of parking should dampen automotive-travel demand, at least to some extent.

Long-Term Effectiveness in Reducing Congestion

Rating: Low. On-street-parking restrictions create more lane capacity in the short term, which is likely to produce noticeable reductions in traffic. In the longer term, however, the initial benefits may erode as additional drivers, noticing that the route is now flowing more smoothly, begin to converge on the newly freed capacity. The one circumstance in which this would not occur is when the new lane capacity is allocated to other uses, such as dedicated transit or cycling lanes (Booz Allen Hamilton, 2006).

Evidence from London demonstrates the relative ineffectiveness of additional lane capacity in the longer term. While selective increases in road capacity have reduced traffic delays on some parts of the network, the many previous attempts to increase lane capacity throughout the city have not been successful in producing sustained traffic reductions at the network level. In fact, when London *removed* some of the capacity expansions introduced in previous decades (e.g., using one lane of a short section of dual carriageway for buses, allowing parking on sections of road previously designated as urban clearways), it did not produce a significant detrimental effect on traffic flow (London Assembly, 2002). In the longer term, then, traffic flow appears to adjust to available lane capacity.

Parking-restraint measures can also result in spillover impacts in the adjoining areas as drivers adjust their behavior. When parking supply has been restricted in city centers, commuters have moved farther out and parked in the inner city suburbs, thus encroaching on the parking available to local residents and creating traffic congestion in those neighborhoods (Booz Allen Hamilton, 2006). Hence, parking restrictions may not necessarily reduce congestion at the regional level; rather, they may simply push the congestion to another part of the network.

Mobility, Accessibility, and Traveler Choice

Rating: Good (uncertain). By increasing lane capacity and thus reducing congestion (at least for the short term), on-street-parking restrictions should promote enhanced mobility. If the curb lane is reserved for transit vehicles, it will also enhance alternatives to automo-

tive travel. On the other hand, parking restrictions may reduce accessibility for drivers wishing to go where the on-street parking has been removed. We suspect that the overall benefits will exceed the disadvantages, but the net effects may vary from one context to another. For this reason, we characterize our rating of *good* as being *uncertain*.

Safety

Rating: Good. Some opponents of on-street-parking restrictions argue that parked vehicles buffer pedestrians from the through traffic. Others argue that parked vehicles obscure the vision of pedestrians and drivers crossing the intersection. For instance, in a study of pedestrian injuries in accidents involving children, the number of parked vehicles was the strongest risk factor on residential streets (Agran et al., 1996). In addition, Shoup (2005) argued that the act of curbside parking is itself a considerable source of accidents, as vehicles will often stop or veer suddenly when they see a space that is about to be vacated. Research findings suggest, in fact, that between 40 and 60 percent of all midblock arterial accidents involve parking (Weant and Levinson, 1990).

Economic Efficiency

Rating: Good. By expanding effective lane capacity, curbside-parking restrictions allow arterial routes to carry more traffic at little or no net cost. This promotes greater economic efficiency in the use of existing roadway investments.

With respect to the economy in general, another interesting question is how curbside-parking restrictions may affect business and retail activities along the affected corridors, and here the evidence appears to be mixed. One modeling study compared how the reduction in available parking would affect workers versus nonworkers. The results showed that workers were more likely to change their time or mode of travel than to change destination or cancel their activity. Nonworkers might change their time or mode of travel as well, but they were also likely to change destinations or cancel their activity entirely. These results suggest that parking restrictions may be effective in reducing congestion in the business district (based on workers' willingness to change

their time or mode of travel), but they may also negatively affect the vitality of the business district if shoppers and other visitors choose to patronize alternative locations in response to the reduced parking supply (Shiftan and Burd-Eden, 2007).

Although restricting on-street parking may discourage patronage of businesses in the area, traffic congestion may also deter visits to city centers. Recognizing the need for balance, some cities have restricted on-street parking to alleviate congestion while providing additional off-street-parking facilities. This strategy maintains or increases the number of parking spaces while enhancing the capacity of the access roads to the town center. The resulting reduction in congestion allows those visitors arriving by car to reach their destination more efficiently. However, this is, at best, a short-term solution, as it has been established that an increase in parking and road space leads to a complementary increase in car use and, in turn, greater congestion over time (BMA Transportation Services, 2007).

Another study evaluated the economic effects of parking restrictions in various European cities, including Edinburgh, Frankfurt, Rotterdam, and Zürich. All of these cities continued to experience a high automobile mode share for home-to-work trips even after restrictive parking policies were enacted. The study also found that parking restrictions would not have negative economic impacts if implemented in a city with a strong and vibrant economic structure (Martens, 2005).

Environment

Rating: Neutral (uncertain). The longer-term environmental effects of parking restrictions are uncertain and likely context-dependent. If on-street-parking restrictions reduce congestion, then cars will spend less time idling and emitting excess pollutants. In addition, as described, reducing parking supply may stimulate a shift to less-polluting modes of travel, such as transit, biking, or walking. On the other hand, increasing road capacity through the reduction of parking may also attract more vehicles to the road, counteracting the initial environmental benefits. Furthermore, the decrease in parking supply may increase the amount of time that some cars spend searching for parking on neigh-

boring side streets, and this would also consume more fuel and emit more pollutants.

Stuttgart's Clean Air Programme favors the elimination of short-duration parking spaces rather than long-duration ones. It is argued that short-duration parking induces more car arrivals and departures, thereby generating more car trips and search traffic (Topp, 1991). In some cities, after implementing parking restrictions, the remaining parking spaces were converted to short-term shopper parking in order to maintain economic vitality. This, of course, increases vehicle turnover with corresponding implications for emissions (London Assembly, 2002).

Equity

Rating: Bad/can partially mitigate—>neutral. Parking restrictions may be negative from an equity perspective in the sense that the costs and benefits are not evenly distributed. Drivers (and transit riders) using the corridor will benefit from the increased flow capacity, while local businesses may suffer as their patrons find it more difficult to park in the area (O'Fallon and Sullivan, 2003). The burden on local businesses can be mitigated, at least to some extent, by improving transit access along the corridor, by providing shared off-street parking resources, or by applying parking restrictions on busy arterials throughout a region such that different business districts remain on an equal footing.

Stakeholder Concerns

Rating: Medium/difficult to address—>medium. Local business owners, as just noted, constitute one group that will likely object to curbside-parking restrictions, especially in areas where off-street parking is scarce. Developers may also object if the absence of curbside spaces means that they need to provide additional (and costly) off-street parking for projects in the area. Nearby residents may be concerned that drivers looking for a place to park may spill into their neighborhoods in search of a space. Finally, drivers may themselves object if the curb lane is dedicated to transit use once the parking spaces are restricted. Many of these concerns can be addressed through complementary strategies. For instance, transit services to the area can be improved, and negative

reactions to the dedication of curb lanes to transit can be reduced if it is shown that bus patronage along the corridor exceeds the number of drivers that could be accommodated in the same lane. Parking districts can be created to establish shared off-street parking facilities, and parking in nearby neighborhoods can be restricted to residents only (or metered for nonresidential use with revenues returned to the residents for local public improvements; Shoup, 2005). A gradual or phased process of implementation may also abate some of the opposition (Booz Allen Hamilton, 2006).

That said, many of the complementary strategies are difficult to implement, especially in the near term. For example, enhancing transit service to an area requires additional revenues, and many transit providers already face challenging budgetary constraints. Developing parking districts will likely require the provision of new off-street parking facilities, and this requires both land and money. Accordingly, though complementary strategies exist, we would still describe the stakeholder concerns, rated as *medium*, as being *difficult to address*.

General Political Obstacles

Rating: Low. While parking restrictions may have negative effects on specific stakeholder groups, they will likely improve (at least for the short term) traffic conditions for a large share of travelers. Many residents of a region may thus favor this policy, and, as a result, the general level of political obstacles (beyond specific stakeholders) should be relatively low. As noted in one report (Booz Allen Hamilton, 2006), general consensus for parking restrictions can be cultivated when the conditions are favorable. Such conditions would include high levels of traffic congestion on roads leading to the affected area, high levels of public transit available for trips to the area, and community-wide support for clean transport. Zürich is an example of a city in which community support for clean transport has been strong enough to override the opposition of certain groups to curbside-parking restrictions.

Institutional Obstacles

Rating: Medium/difficult to address—>medium. Current parking policies in many cities are predicated on the assumption that max-

imizing available parking capacity is a desirable end (Shoup, 2005). On-street-parking restrictions challenge this assumption, representing a significant change from current practices. Consequently, this strategy may require overcoming bureaucratic and institutional inertia. Education may play a key role in this regard, especially in the longer term. Specifically, it may help to familiarize public officials, planners, and business leaders with the growing body of research demonstrating that a plentiful supply of free parking encourages additional driving and, in turn, more congestion and to provide them with information about the wide range of innovative parking-management strategies and their potential benefits (see, for example, VTPI, 2008d). Some of these strategies require changing current development, zoning, and design practices. It may also be helpful to approach the issue of parking in a comprehensive manner, developing a coordinated set of policies across the region to address such issues as enforcement, spillover impacts, and economic effects. Such changes take time, however, so we would characterize the institutional challenges, rated as *medium*, as being *difficult to address* in the short term.

Current Status in the L.A. Region

Rating: Moderate. Various cities in L.A. County have implemented curb-lane-parking restrictions in one form or another. The City of Los Angeles, in particular, has pursued the strategy much more aggressively in recent years. For instance, LADOT recently conducted a study of the most congested signalized intersections in the city as part of OBR. Of the 98 intersections studied, 14 were recommended for further operational or capital improvements, including street widening or parking restrictions, to facilitate the installation of additional travel lanes. The City has since continued to identify and evaluate additional congested intersections for similar treatment (Fisher, 2006). The City has also established peak-hour-parking bans on selected arterials.

LADOT recently conducted a comprehensive parking study examining the agency's organization, operations, and roles in relation to the planning and management of parking resources in the city (d'Amato, 2006). The study proposed a coordinated set of parking strategies to serve both short-term needs and longer-term goals. Park-

ing policy in Los Angeles faces the twin challenges of accommodating economic growth while reducing traffic in a heavily car-dependent city with less land available for off-street parking and more pressure at the curb to accommodate new and overflow demand. On-street-parking policies also need to address the competing needs of transit, taxis, loading zones, and commercial interests and user groups.

To reduce traffic congestion on the arterial network, the City has eliminated on-street parking along many of the most crowded corridors to provide an additional travel lane during peak periods, thereby enhancing the network's flow capacity. This, however, results in forgone meter revenue as well as the potential loss of customers for businesses along the affected corridors. LADOT's recent parking study suggests several ways for addressing these concerns. For instance, the City could change meter hours to better coincide with business-customer needs. The price for parking at the curb could also be raised to promote shorter-term parking and higher turnover rates as well as to increase revenue to offset the loss from peak-hour-parking restrictions. On-street parking could also be better regulated to maximize customer access while encouraging longer-term customer and employee parking in off-street facilities (d'Amato, 2006).

To improve the enforcement of peak-hour parking restrictions (7:00 to 9:00 a.m. and 4:00 to 7:00 p.m.) on some of the busiest arterial travel corridors, LADOT recently established a Tiger Team consisting of 15 parking-enforcement and traffic-control officers along with 10 tow trucks. When the Tiger Team detects a peak-hour parking violation, it quickly responds to both cite and tow the offending vehicle. The citation fee is \$65, and the towing fee is \$144 plus an additional \$33 for each day that the towing operator holds the vehicle before the owner reclaims it (L.A. Office of the Mayor, 2006). The Tiger Team began operations on Wilshire Boulevard, issuing more than 17,000 parking citations and towing almost 5,500 vehicles in a single year. The Tiger Team program has since been expanded to two other heavily traveled corridors in Los Angeles, Vermont Avenue and Ventura Boulevard (L.A. Office of the Mayor, undated).

Interaction with Other Strategies

If reducing congestion is the ultimate goal, parking restrictions may be most effective when combined with improvements in alternative modes, such as transit services. Parking restrictions provide a motivation for switching from the car to some other mode, while improved transit services make it more feasible to make this switch. Moreover, by creating additional lane space, parking restrictions provide an opportunity to develop bus-only lanes in heavily patronized transit corridors (see Appendix B25).

As a corollary, improvements to public transit absent strict parking restrictions are less likely to lure motorists out of their cars. Parking restrictions support improved transit as well as other TDM strategies by making driving alone either less convenient or more expensive. By the same token, absent improvements in alternative modes of travel, drivers may have little option but to continue traveling by car and either search for parking in surrounding neighborhoods or pay to park in off-street facilities (Booz Allen Hamilton, 2006).

Other research supports the importance of this connection. A study by O'Fallon and Sullivan (2003) examined the effects on travel to routinely attended destinations (such as jobs or school) resulting from improvements to transit, such as reduced fares and more frequent service. Absent complementary disincentives to driving—road pricing, higher parking charges, or parking restrictions—very few travelers switched from driving to transit. The authors argued that the transit improvements would have been much more effective had they been accompanied by complementary measures to reduce the convenience or raise the cost of traveling by car.

In another study, Mildner, Strathman, and Bianco (1996) examined the relationship between parking management, transit service, and transit ridership in 20 large U.S. cities. They found that cities with both a restrictive parking policy (high cost or low supply) and high levels of transit service were much more likely to have high transit-ridership levels than cities with less restrictive parking policies or lower levels of transit service.

One-Way Streets

After the Second World War, rapid growth in the use of private automobiles enabled a massive exodus of urban dwellers moving to the suburbs, though many continued to work in the cities. This dramatic shift in residential and commuting patterns led to much higher traffic volumes, along with an increasing number of vehicle collisions on arterial routes leading into and out of the cities. To move traffic more quickly and safely, many cities began to convert former two-way streets to one-way operation (Cunneen and O'Toole, 2005; Walker, Kulash, and McHugh, 1999). Today, one-way-street alignments remain quite common in major activity centers—such as the CBDs in downtown Los Angeles, San Francisco, and New York—characterized by heavy traffic volume and closely spaced intersections. In the development of new activity centers, such as shopping centers, sports arenas, and industrial parks, one-way streets are frequently incorporated into the original street and traffic plans.

One-way streets are generally operated in one of three ways (Meyer, 1989):

- as a street on which traffic moves in one direction at all times
- as a street that is normally one-way but at certain times may be reversed in direction to provide additional capacity in the direction of highest travel demand
- as a street that normally carries two-way traffic but at certain times may be operated as a one-way street flowing in the direction of peak travel.

One of the reasons that one-way street alignments have remained popular is that they can often reduce traffic and increase overall throughput capacity (Meyer, 1989). With one-way streets, traffic signals can be timed to optimize flow in a single direction of travel. This is more difficult on streets on which traffic flows in both directions, given that the optimal timing for traffic signals in one direction would likely result in delays for traffic heading the opposite direction. Additionally, it is faster and safer for drivers to make left turns on one-way streets because they do not need to contend with traffic heading in the opposite direction. The potential to achieve such improvements motivated a recent proposal, proffered by city and county officials in Los Angeles, to convert Pico and Olympic Boulevards to a system of paired one-way streets, with one facilitating eastbound traffic and the other serving westbound traffic (Hyman, 2007; Rifkin, 2007).

Yet despite their benefits, the popularity of one-way streets is far from uniform. In many cities across the United States—such as Albuquerque, Austin, Berkeley, Cambridge, Chattanooga, Cincinnati, Louisville, Norfolk, Palo Alto, Sacramento, San Jose, Seattle, St. Petersburg, Tampa, and Toledo—the trend has been to convert systems of one-way streets back into two-way operation. This has led to significant controversy, especially in Austin, Cincinnati, and Chattanooga (O’Toole, 2003). In most of these cities, the primary motivation for one-way to two-way street conversion plans was to help revitalize downtown districts into bike- and pedestrian-friendly residential and commercial districts. Two-way streets are generally considered to have lower vehicle speeds than one-way streets and are thus more accommodating to pedestrians and bikers. Another advantage is that two-way streets make it easier for motorists—especially those unfamiliar with an area—to navigate from one point to another. On the other hand, such changes can also degrade the flow of traffic moving through an area, frustrating many motorists who would prefer higher travel speeds to a higher-quality environment for pedestrians and cyclists.

Evaluation of Strategy

Cost/Revenue Implications

Rating: Medium cost. According to one estimate, the basic costs associated with converting two-way streets to one-way streets range from about \$500 to \$2,000 per block (TTI, 2001). FHWA estimates the cost of conversion in the range of \$20,000 to \$200,000 per mile, depending on the length of treatment and whether the conversion requires signal modifications. Elements that may add to the cost of conversion include the construction of crossovers (where a one-way street converts back to two-way operation), replacing traffic signals, restriping lanes, and adding signs and parking meters along curb lanes (Harkey and Zeeger, 2004). If many two-way streets throughout Los Angeles were to be converted to one-way operation, the costs could quickly escalate into the millions or tens of millions of dollars.

Although the costs are significant, some consider one-way streets a cost-effective strategy that can provide additional lane capacity for a fraction of the price of investing in new or expanded arterials (Meyer, 1989).

Short-Term Effectiveness in Reducing Congestion

Rating: Medium. This strategy will likely have a *medium* level of short-term effectiveness in reducing congestion by both increasing capacity and reducing delays. Specifically, the benefits of one-way streets include the following (Meyer, 1989):

- allowing existing lanes to be widened or new lanes to be added, since a median strip between opposing directions of flow is no longer needed
- making it easier to time signals to promote a smooth progression of traffic from one intersection to the next
- making it easier, faster, and safer to make left turns, including turns onto smaller streets between major intersections, which might not be possible with median-separated two-way operation
- redistributing traffic to relieve congestion on adjacent streets

- permitting faster public-transit routings with turn-back loops, in which buses can travel in one direction on one street and then return on a parallel street on which traffic flows in the opposite direction
- facilitating the unloading of commercial vehicles with reduced impact on traffic flows.

Based on such advantages, according to one report, a street lane's effective capacity may be increased by as much as 50 percent when converted from two-way to one-way operation (TTI, 2001). An important factor in this gain is the improvement in left-turn capabilities. On a two-way street, the left-turn lanes are near the center of the street. Regardless of the volume of left-turning vehicles, the net effect is that a lane must be reserved for this group of vehicles and thus no longer serves through traffic. If there is a significant volume of left-turning traffic, the volume may overflow onto the adjacent through lanes, contributing to further delays. Such situations can warrant a dedicated left-turning signal phasing, which introduces delays to through traffic in the opposite direction. With a one-way street, in contrast, left-turning vehicles are placed on the left side of the street and can make their turns immediately because there is no oncoming traffic with which to contend. Because drivers need not wait to make a left turn, the left lane can be shared by both left-turning and through traffic, effectively adding a full lane to the street's capacity. In addition, depending on the traffic-flow operation of the cross street, it may be possible to allow left turns on a red signal. This option will further reduce vehicle delay at an intersection (Stemley, 1998).

The advantages related to signal timing are also significant. On a one-way-street network, signal timing can be synchronized to allow progressive movement in all directions at reasonable speeds. With systems of two-way streets, however, the left-turn signals pose a challenge for optimal signal timing. It has been estimated that signal timing for a two-way street network could perform as well as that for a one-way street network only if the signals are at least a half-mile apart, a much greater spacing than is found in most urban environments. In most cases, then, synchronized signals can allow for higher average

speeds on one-way streets than on two-way streets. Faster speeds due to more effective signal synchronization combined with less delay for left-turning traffic will tend to result in shorter travel times for vehicles on one-way streets (O'Toole, 2003). In cases examined by Stemley (1998), creating one-way streets resulted in reductions in intersection delays of almost 50 percent, along with trip-time reductions of 22 to 33 percent.

In addition to increasing the average travel speed, progressive synchronization of traffic signals on one-way streets may also lessen stop-and-go movement. Most drivers prefer a slow but steady movement over stop-and-go movement, even at higher speeds, and the use of one-way streets is reported to reduce the number of stops by nearly 66 percent (Stemley, 1998). Another study found that, after converting two-way streets to one-way operation, drivers experienced 60 percent fewer stops, which led to a 19-percent increase in traffic speed (Cunneen and O'Toole, 2005).

If switching from two-way to one-way streets reduces delays and improves travel times, converting from one-way back to two-way streets should have the opposite effect. A feasibility study to assess the traffic-related effects of converting the existing one-way-street grid system in downtown Dayton, Ohio, to a two-way-street grid system confirmed this hypothesis. The study evaluated four two-way network scenarios and compared them to the existing one-way system:

- all north-south streets two-way and all east-west streets one-way
- all east-west streets two-way and all north-south streets one-way
- all two-way streets with reductions in on-street parking
- all two-way streets, preserving the existing supply of on-street parking.

The study found that, for all of the two-way scenarios, there would be an increase in intersection delay of up to 45 seconds during commuting hours (Parsons Brinckerhoff Ohio, 2004).¹

¹ The researchers concluded that this level of delay was acceptable according to the Ohio Department of Transportation level-of-service standards and recommended the option in

Though one-way operation may reduce intersection delays and improve travel speeds, it should also be noted that one-way operation will increase the required travel distance for many trips. If drivers want to turn one direction on a street but traffic flow is headed in the opposite direction, they will have to continue until they find another street headed in the right direction and then circle back to the original street. In a pattern in which every other street is oriented in a different direction, motorists will have to perform such maneuvers on a regular basis, leading to increased trip distances and, in some cases, increased travel times (Block, 1980). Furthermore, while one-way streets facilitate improved signal timing for through traffic, it can be more difficult to develop effective signal timing for arterials that cross paired one-way streets (Harkey and Zeeger, 2004).

Long-Term Effectiveness in Reducing Congestion

Rating: Low. Though one-way street alignments may produce short-term reductions in congestion, these benefits are not likely to last. With the phenomenon of triple convergence, as travelers notice that one-way arterials are now flowing more smoothly, more will choose to use those arterials during peak hours. Congestion will then slowly but steadily return to its former level. To illustrate this point, consider the fact that many one-way streets were originally implemented following World War II. Decades later, many of these one-way streets are just as congested as their two-way counterparts.

Mobility, Accessibility, and Traveler Choice

Rating: Good. One-way street alignments effectively increase the arterial system's capacity. Even if, over time, triple convergence erodes benefits related to reductions in delay and increased travel speeds, the system will still be able to accommodate more total vehicles, thereby promoting greater mobility. Public transit operating on one-way streets will also benefit from improved traffic flow and may therefore attract greater ridership. On the other hand, as already described, one-way

which all streets would be converted to two-way operation, maximizing capacity of the two-way streets by eliminating many of the on-street parking spaces.

street alignments can make it more difficult for motorists to navigate from one point to another, as they will often need to bypass one street in order to find another that is headed in their intended direction of travel. In addition, the higher travel speeds associated with one-way streets, as well as the typical absence of medians, may make such streets seem less hospitable to pedestrians. On balance, however, the advantages for additional travel benefits outweigh the disadvantages, thus resulting in a rating of *good*.

Safety

Rating: Good (uncertain). The bulk of available evidence suggests that one-way streets lead to improved safety outcomes. Specifically, they can help reduce vehicle-pedestrian and vehicle-vehicle conflicts at intersections, help prevent pedestrians from becoming trapped between opposing traffic streams, and help improve a driver's field of vision at intersection approaches (Meyer, 1989). That said, other studies suggest that, under certain circumstances, one-way streets may actually be more dangerous. For this reason, we describe our rating of *good* as being *uncertain*.

Many cities throughout the United States have experienced reductions in vehicle and pedestrian accidents on one-way streets. The Oregon Department of Transportation reported that cities in that state experienced an average of 10 percent fewer accidents on one-way streets than on two-way streets, even though the one-way streets carried about 23 percent more traffic volume than two-way streets. In Portland, for example, one-way streets had 51 percent fewer accidents at intersections and 37 percent fewer between intersections. In another study, Sacramento had 14 percent fewer accidents on streets converted to one-way operation, even though there was a 17-percent overall increase in accidents across the city during the period of observation (Cunneen and O'Toole, 2005). The conversion of Fifth Avenue in New York to one-way operation led to improved travel times as well as a reduced collision rate. Despite a 19-percent increase in traffic volume afforded by one-way operation, travel times decreased by 37 percent, and the number of stops at intersections was reduced by 60 percent. The total

accident rate declined by 32 percent, while accidents involving pedestrians of decreased by 29 percent (TTI, 2001).

Additional studies have shown that the rate of pedestrian accidents is higher on two-way streets than on one-way streets. In Sacramento, two-way streets produced 163 percent more pedestrian accidents, while, in Portland and Raleigh, the rate of accidents with pedestrians was approximately 100-percent higher for two-way streets than for one-way streets (Cunneen and O'Toole, 2005). According to an FHWA report (Campbell et al., 2003) that reviewed a selection of studies on pedestrian safety, two-way streets generally experience a higher rate of accidents involving pedestrians than one-way streets, even though the latter are likely to be wider and carry heavier volumes of automobile and bus traffic. One study suggested that conversion to one-way street alignment may be a relatively low-cost measure for improving pedestrian safety, having as high as a 40- to 60-percent level of effectiveness for reducing crashes. One-way-street intersections simplify crossing and turning conditions for both vehicles and pedestrians. Pedestrians have to look in only one direction when crossing one-way streets. Left-turning motorists do not have to negotiate with oncoming traffic, and, as a result, they can focus more of their attention on looking out for pedestrians. The reduced complexity of executing turns proves to be especially helpful in reducing the crash rate. Although vehicle-turning movements accounted for just 14 percent of the total intersection volume in the cases reviewed in the FHWA study, crashes involving turning vehicles represented 45 percent of the total rate. Turning left at an intersection of two-way streets is a considerably more challenging and dangerous maneuver than either right or left turns at an intersection of two one-way streets (Campbell et al., 2003).

From a technical perspective, one of reasons that one-way streets may be safer for pedestrians is that an intersection of these streets has fewer points of potential conflict between vehicles and pedestrians. For example, in an intersection of two-way streets with single through-lane approaches, with right and left turns permitted, and with right turns permitted on a red light, a vehicle could strike a pedestrian at 20 different points. For the intersection of two one-way streets, in contrast, there are only four conflict points (Stemley, 1998).

In contrast to the evidence just discussed, other reports have suggested that one-way streets offer little in the way of safety benefits and, in fact, may even be more dangerous. Another report (Zeeger et al., 2005), for instance, found no correlation between the rate of pedestrian crashes and whether the road operated with one-way or two-way traffic. It did find that raised medians provided significantly lower pedestrian-crash rates. Medians are generally not found on one-way streets but on two-way streets. Some also argue that one-way streets are more dangerous to pedestrians because one-way streets yield more possible types of intersections. A one-way street can intersect with another one-way street or with a two-way street, and the variability of resulting intersection configurations can create more confusion for pedestrians and motorists (Walker, Kulash, and McHugh, 1999).

While studies have shown that converting two-way streets to one-way generally reduces pedestrian crashes, one-way streets tend to have higher speeds, which creates new safety problems (Harkey and Zeeger, 2004). Moreover, one-way streets could lead to confusion and collisions when vehicles enter a one-way in the wrong direction. Infrequent users of one-way streets, unfamiliar with the one-way network in a city, are more likely to make such a mistake (Stemley, 1998). Prevention of this type of conflict relies on effective signage and drivers' ability to detect and understand the signage. This may place new visitors to an area, as well as some elderly drivers, at a disadvantage.

Another study (Wazana et al., 2000) focused specifically on child pedestrian-injury rates on one-way streets and two-way streets in Hamilton, Montreal. Results of the study indicated that the accident rate was 2.5 times higher on one-way streets than on two-way streets, and it was three times higher for children from the poorest neighborhoods than for those from wealthier neighborhoods.

For emergency vehicles, the picture is somewhat mixed. Emergency vehicles may be able to reach a destination more directly on two-way streets than on a one-way-street network. On the other hand, emergency vehicles may be able to travel to the scene of an incident more safely on one-way streets, since they do not have to enter oncoming traffic lanes (Stemley, 1998).

For cyclists, one-way streets interrupt many direct connections and make the use of low-traffic local streets more difficult. In turn, this may motivate cyclists to travel illegally on one-way streets or to travel on sidewalks. To improve cyclist safety on one-way streets, Germany has implemented contraflow bicycle lanes on some one-way streets. A study evaluating collisions involving cyclists on one-way streets with and without contraflow bike lanes showed that bicycle-motorist collisions are more common when bicyclists are traveling in the same direction as cars, while bicycle-pedestrian conflicts are more common when bicyclists are traveling in contraflow lanes. That said, the overall rate of accidents involving bicyclists on one-way streets with and without contraflow lanes is about the same (Alrutz et al., 2002).

Economic Efficiency

Rating: Good. One-way street alignments represent a relatively cost-effective strategy for enhancing an arterial system's capacity (as compared to, say, building new lane-miles). As such, they may be rated as *good* with respect to economic efficiency.

Another economic issue worthy of discussion is the effect for local businesses. Many cities in the United States are in the process of converting one-way streets in their downtown districts back to two-way streets as part of a strategy to revitalize the downtown area. The logic for this switch is that it will reduce traffic speed and thus create a more pedestrian-friendly environment. By increasing pedestrian traffic, the level of downtown business activity may improve. Furthermore, slower-moving vehicles are more likely to notice and patronize small stores along a street (Eversley, 2006).

Another argument made by those who advocate the conversion of one-way streets to two-way operation is that one-way streets may hamper business by forcing many drivers to circle around the block, following the one-way flow direction, to reach their desired destinations. Such inconvenience may discourage some potential patrons. Advocates of one-way streets, in contrast, argue that one-way alignments will reduce congestion and therefore encourage more people to travel to downtown (O'Toole, 2003). Also, the additional lane capacity made possible with one-way alignments may permit part- or full-time

parking that would otherwise be infeasible with two-way operation. The availability of storefront street parking should facilitate additional patronage for such businesses (TTI, 2001). Supporting the case of one-way-street advocates, the land values along a street in New York City that was converted from two-way to one-way operation increased by nearly 60 percent (Stemley, 1998).

All else equal, certain types of businesses will likely benefit more from one-way streets than others. For example, high-volume businesses with their own parking lots, such as supermarkets, would do well on one-way streets. On the other hand, specialty stores that rely on impulse shoppers may do better on slower-moving two-way streets, where motorists are more likely to notice the stores as they pass by (O'Toole, 2003).

Environment

Rating: Neutral. One-way-street networks enable progressive signal synchronization such that cars experience less stop-and-go driving than they would on two-way streets. Because cars pollute more when they must frequently decelerate and then accelerate again than they do when moving at a more constant speed, one-way streets can result in significant reductions in pollution per VMT compared to two-way streets (O'Toole, 2003). Moreover, converting two-way streets to one-way streets is one way to increase effective arterial capacity without building new streets (TTI, 2001), another environmental plus.

On the other hand, to increase the capacity of two-way streets, it may be necessary to sacrifice street frontage assets, such as sidewalks, trees, and other vegetation, in order to widen the roadway (TTI, 2001). Another environmental disadvantage of one-way streets is that they force additional turns at intersections for motorists who must travel out-of-direction to reach their destinations—that is, motorists who must bypass a road heading in the wrong direction to find a street headed in the right direction and then eventually circle back to the intended destination. The additional turning movements for a one-way-street network result in a systemwide increase in VMT as compared to a two-way street network (Meng and Thu, 2004). The increase in VMT produces more pollution and fuel consumption. The required

detours through a one-way-street network may also mean greater travel distances for cyclists, which may encourage some to choose to travel by car instead (Gasson, 1999). Finally, to the extent that one-way streets effectively increase capacity and reduce travel times, they will enable even more drivers to use the arterials. With more cars come more emissions. Given both the potential advantages and disadvantages, the strategy is rated as *neutral* with respect to environmental outcomes.

Equity

Rating: Neutral. With respect to equity concerns, one-way streets offer both potential benefits and drawbacks. On the positive side, greater travel speeds and fewer intersection delays on one-way streets will benefit not just motorists but bus riders as well. Because a larger share of bus riders are from lower-income and racial and ethnic minority communities, this feature will tend to improve equity outcomes (Stemley, 1998).

On the other hand, buses traveling in opposite directions on a system of one-way streets must use adjacent streets rather than the same street. As a result, transit users may have to walk farther to reach transfer points or to catch a return bus. Moreover, novice bus riders may become confused in finding return service (Stemley, 1998). This characteristic of bus service on one-way streets will tend to diminish equity-related benefits. Also, a study by Wazana et al. (2000) found that pedestrian accidents involving children are 2.5 times higher on one-way streets than on two-way streets and three times higher for children from the poorest neighborhoods. Because lower-income households remain concentrated in and around downtown areas, and because one-way streets are more common in downtown areas than in surrounding suburban areas (O'Toole, 2003), this finding also bodes negatively for equity concerns.

Stakeholder Concerns

Rating: High/can partially mitigate—>medium. Business owners, especially those who run smaller retail outlets, are likely to oppose one-way streets because they believe that the faster-traveling drivers are less likely to notice the storefront businesses and patronize them.

Strong opposition to one-way streets also may arise from community residents. To begin with, some may be concerned about the higher speeds at which vehicles typically travel on one-way streets. Others will object to the potential for greater cut-through traffic, where vehicles on one street that need to head in the opposite direction make use of perpendicular residential streets to reach another one-way thoroughfare oriented in the intended direction of travel. Such concerns have been raised, for example, with the recent proposal to convert Pico and Olympic Boulevards to one-way operation (Hyman, 2007). Finally, groups that advocate for improved pedestrian and bicycling environments may resist the implementation of one-way streets, preferring instead the slower-moving traffic conditions that characterize most two-way streets.

Many of these concerns can be at least partially mitigated. For example, stricter speed limits combined with effective enforcement can be used to prevent excessive travel speeds. Turn prohibitions, meanwhile, can reduce the number of vehicles that cut through residential neighborhoods to reach a street headed in the opposite direction. Contraflow bike lanes may also be added to improve mobility for cyclists.

General Political Obstacles

Rating: Low. Whereas the individual stakeholder groups just discussed may oppose one-way streets, other residents who use the streets for commuting or other travel purposes are likely to favor the increased travel speeds and reductions in intersection delays. Thus, there is not likely to be a significant level of general political opposition to one-way streets—rather, opposition will be concentrated among a few concerned stakeholders.

Institutional Obstacles

Rating: Medium/difficult to mitigate—>medium. One-way-street conversions that fall entirely in a single city pose few institutional obstacles. Many of the longer boulevards in the L.A. region, however, cross many city boundaries, and this does raise institutional challenges. If one city wishes to convert a two-way street to one-way operation and an adjacent city does not, the overall benefits for improving traffic flow

will be suboptimal. To achieve maximum benefits, the street should be converted for a long, continuous stretch, and this will often require cooperation and coordinated action among multiple municipalities.

Current Status in the L.A. Region

Rating: Limited. In L.A. County, most of the one-way streets are in downtown districts, most notably downtown Los Angeles. Recently, however, Mayor Antonio Villaraigosa announced a plan, following up on an earlier proposal prepared for County Supervisor Zev Yaroslavsky (Rifkin, 2007), to implement a system of paired, quasi-one-way streets involving Pico and Olympic Boulevards outside of the downtown district. To accommodate the growing travel demand of commuters heading into and out of Santa Monica and the western portions of Los Angeles, the goal of the plan is to significantly reduce travel times on these major arterials by making them behave more like one-way streets while keeping them two-way streets. This would be accomplished by restructuring the operation of the boulevards to provide a decided time advantage to those traveling east on Pico and those traveling west on Olympic. The first step would be to eliminate curbside parking on both streets during the rush-hour period. Next, traffic lights would be retimed so that those traveling east on Pico and west on Olympic would be rewarded with longer green lights. If these two steps prove successful, the city might then convert most lanes on Pico to eastbound and most lanes on Olympic to westbound. City officials project that such steps could reduce travel times in the primary direction along these boulevards by as much as 45 percent (Hymon, 2007).

Interaction with Other Strategies

Optimizing the performance of one-way streets requires effective signal timing and control (see Appendix B2). Using detectors, sensors, or traffic cameras, signal synchronization can be properly adjusted for current traffic volumes on the road network. During periods of high demand, signals can be programmed to prioritize progressive movement along one-way streets. When travel demand is lower, the relative priority between one-way streets and perpendicular two-way streets can be modified accordingly. One-way streets, in addition to benefiting

motorists, are complementary to improved bus service as well, and converting two-way streets to one-way operation may provide the opportunity to create dedicated bus-only lanes (see Appendix B25). With the addition of contraflow bike lanes, one-way streets can also improve (or at least not diminish) opportunities for cycling (see Appendix B28).

Rush-Hour Construction Bans

Construction and maintenance work—such as repaving roads, repairing potholes, expanding existing lanes, or adding new lanes—occur frequently on highways and local streets throughout the United States. Other public infrastructure projects, such as repairing power lines and water systems, may also affect the road network. While such activities serve the public good, they can also create roadblocks that exacerbate traffic congestion. To mitigate the negative impact of construction activities, construction could be banned during certain hours or days. Construction can be prohibited during the morning and evening peak commute hours, during all daylight hours, or even on certain holiday or special-event days.

On the Connecticut Turnpike, the application of construction bans has resulted in the vast majority of work being performed between the hours of 8:00 p.m. and 6:00 a.m. Because this facility carries roughly 120,000 vehicles per day and operates at close to 185 percent of its target capacity during peak hours, shifting construction to the nighttime hours was judged to be a cost-effective strategy for preventing additional congestion on the turnpike, even though after-hours construction typically entails higher labor rates (Banfield, 1999). Construction bans can also be implemented to achieve air-quality goals. In 2005, the Dallas/Fort Worth Metroplex area in Texas, as part of its efforts to comply with the Clean Air Act (P.L. 88-206), implemented a rush-hour ban on construction equipment with diesel engines of 50 horsepower (hp) or more between 6:00 a.m. and 10:00 a.m. from June through August (EPA, 2002).

Many cities in the United States and other countries are actively pursuing efforts to revitalize and expand their economies, and a necessary part of such growth is construction. With increases in construction, however, come increases in traffic congestion, and this can frustrate many residents. In response to such frustration, officials in Shanghai have imposed a rush-hour construction ban, and they are considering banning construction on any new roads for at least three years following the initial construction of the roads (China, 2006). The City of Los Angeles has also established a rush-hour construction ban as of August 12, 2005 (BOE, 2006).

Evaluation of Strategy

Cost/Revenue Implications

Rating: Low cost. Limiting the hours of the day during which construction can occur may prolong a project's overall duration. In addition, workers will typically receive higher wages for working during late-night hours. On balance, though, the additional costs are relatively modest. In one study, for instance, the base cost of a lane improvement—with work occurring during standard hours—was estimated at around \$500,000. If the work had been shifted to the nighttime hours, the estimated cost increase would have been about \$30,000, or roughly 6 percent (Carr, 2000). As will be discussed in the section on economic efficiency, the economic benefits of the congestion reductions far outweigh the additional construction costs.

Short-Term Effectiveness in Reducing Congestion

Rating: Medium (uncertain). Construction bans do not reduce the level of recurring congestion—that is, congestion resulting from a general mismatch between the road network's capacity and the demand for travel during peak hours. On the other hand, they can prevent additional traffic congestion that would result from lane closures during the busiest times of the day. In areas with a lot of ongoing construction, such as large activity centers, such savings are likely to be considerable. For this reason, we rate the strategy as *medium* with

respect to short-term effectiveness in reducing congestion. That said, we did not encounter much in the way of specific evidence quantifying the congestion-reduction benefits on a systemwide basis, and, for this reason, we describe our rating as being *uncertain*.

Long-Term Effectiveness in Reducing Congestion

Rating: Low. In the long run, triple convergence is likely to erode any congestion-related benefits resulting from rush-hour construction bans. That is, if the use of construction bans results in more freely flowing traffic on the arterial or highway system, travelers will notice these improvements and begin to shift their trips back to the peak hours, thereby undermining the reductions in congestion. In addition, construction bans will do little to stem longer-term growth in congestion resulting from additional travel as the population and economy expand. As an illustration of this finding, Giuliano (1988) noted that many of the TSM approaches implemented in Los Angeles for the 1984 Olympics—including rush-hour construction bans—yielded short-term improvements that did not persist for long.

Mobility, Accessibility, and Traveler Choice

Rating: Good. Construction during the peak hours can create or exacerbate congestion, reducing mobility, accessibility, and traveler choice. Construction often creates physical barriers as well, making it difficult to access certain businesses or travel on certain routes. In some cases, construction may even lead drivers to cancel a trip completely. Accordingly, rush-hour construction bans should enhance mobility, accessibility, and traveler choice.

Safety

Rating: Good. It has been reported that more than 1,000 crash-related fatalities occur each year in highway work zones across the United States, and the number of total crashes is much higher than that. A study in Kentucky, for example, reported an average of more than 600 crashes per year near construction and maintenance work areas in that state alone between 2000 and 2005 (Pigman, Agent, and Green, 2006). Roads are obviously more crowded during peak

hours, so engaging in construction activities during these periods may increase the likelihood of crashes near work zones. In addition, the congestion associated with construction zones during peak travel periods may increase the frustration level of drivers, leading them to engage in hazardous vehicle maneuvers (Pigman, Agent, and Green, 2006). Such logic would argue for banning construction during peak commute hours to reduce these potential safety issues. On the other hand, nighttime construction activities may also introduce dangers, as workers will tend to be less visible to drivers. Furthermore, with a lower traffic volume on the roads at night, the average vehicle speed is likely to be higher. It is possible that these problems can be at least partially mitigated through proper lighting, the presence of traffic officers at the work site, and the placement of appropriate warning signs upstream of the work site. On the whole, provided that such steps are taken, the safety effects of peak-hour construction bans may be positive.

Economic Efficiency

Rating: Good. Peak-hour construction bans will tend to both prolong a construction project's life and increase the wages that must be paid to workers. Provided that the benefits of such bans—in the form of travel-time savings, reduced gas consumption, lower emissions, and fewer crashes—outweigh such costs, peak-hour construction bans may be viewed as increasing economic efficiency. A study by Keoleian et al. (2005) suggested that the social costs associated with construction activities—primarily in the form of congestion delays and the resulting waste of fuel—tend to dwarf the actual construction costs themselves, which would indicate that peak-hour construction bans should, in fact, promote greater economic efficiency. In another study, Carr (2000) examined the effects on total project time, construction costs, and road user costs (including delays and fuel expenditures) for a specific road-improvement project using three alternative construction scenarios:

1. Close the lane and work 10 hours per day, from 7:00 a.m. to 5:00 p.m.
2. Close the lane and work eight hours per day, from 7:00 a.m. to 3:00 p.m.

3. Close the lane and work 10 hours per night, from 8:00 p.m. to 6:00 a.m.

Carr estimated that, with the first alternative, the construction project would be completed in 12 days with construction costs of just above \$500,000. Working during the peak hours, however, would create a two-mile traffic backup with an average delay of six minutes per vehicle, leading to a total cost for road users of about \$444,000. Together, the estimated construction and road-user costs totaled about \$944,000. In the second alternative, which involved slightly fewer hours of construction each day and avoided some of the afternoon peak travel hours, the time required to complete the project extended to a bit more than 15 days, but the reduction in road-user costs was quite modest. With the third alternative, the estimated project duration was the same as in the first alternative, as both involve 10-hour workdays. Because the work hours occurred at night, however, wages were higher, leading to a construction cost of about \$532,000—a roughly 6-percent increase. Avoiding the peak travel hours, however, led to a significant reduction in congestion, with estimated user costs dropping from about \$440,000 to about \$57,000—a decrease of almost 87 percent. Summing construction and road-user costs together, the resulting estimate was about \$590,000. This represents an overall reduction in the total project costs of more than 37 percent. In other words, the social benefits significantly outweighed the costs of shifting construction to the evening hours.

Environment

Rating: Good. Construction sites contribute to both air and noise pollution. The diesel-powered vehicles and equipment used for construction work are typically not fuel-efficient and are likely to produce significant levels of air pollutants. Such equipment is also quite noisy, and the activities associated with construction tend to diminish the aesthetic qualities of the surrounding environment. At the same time, peak-hour lane closures due to construction contribute to additional congestion, and this can also raise the level of pollutant emissions. Banning construction activities during rush hours can thus lead to a

variety of environmental benefits. Specifically, it can help to reduce emissions during the hours when air pollution is most problematic. It can also reduce traffic congestion, which, in turn, reduces emissions and excess fuel consumption from cars stuck in stop-and-go traffic. Finally, it can reduce noise levels during periods when such reductions would be beneficial.

In the Dallas/Fort Worth Metroplex, as mentioned in the introductory passage, a construction ban was established to restrict the use of construction equipment (nonroad, heavy-duty diesel equipment rated at 50 hp and above) until after 10:00 a.m. as an air pollution-control strategy. As a result of this ban, the production of ozone precursors would be stalled until later in the day, when optimum ozone-formation conditions no longer existed, ultimately reducing peak ozone levels. The restrictions applied only from June 1 through October 31, the hottest months. This program, when implemented, was expected to achieve a reduction of about 16 tons of emissions per day, roughly a 30- to 40-percent decrease from the 40 to 50 tons that would be produced without the ban (EPA, 2002).

Some Chinese cities have implemented construction bans to mitigate noise levels during certain periods. One study reported that the noise level 15 meters (m) away from a concrete mixer may rise as high as 86–100 decibels (dB), the noise from pile drivers may reach 110–136 dB, and the noise from heavy trucks may exceed 80 dB. In response to complaints from residents about such noise levels, officials in Nanjing enforced a ban on all construction work during the national entrance examinations for higher-education institutions (X. Liu, 1998).

Equity

Rating: Neutral. Reductions in traffic congestion and air pollutants along with greater mobility and accessibility are likely to benefit drivers, bus riders, and residents from all social and demographic groups. Moving construction to the evening hours may adversely affect construction workers and their families, though, in theory, they are compensated for this inconvenience with higher wage rates during off hours.

Stakeholder Concerns

Rating: Medium/can partially address—>low. The construction industry and other industries that support construction are likely to oppose any restrictions on the hours of construction activities. Such opposition, however, can be addressed through negotiations and compromises. For example, in 1989, the City of Los Angeles implemented a law to shift construction hours from 7:00 a.m.—4:00 p.m. to 6:00 a.m.—3:00 p.m., a change that encountered heavy initial resistance from the construction industry. After some negotiation, though, industry and union representatives eventually agreed to accept the shift and forgo the usual premium pay that they might have demanded for an earlier work-hour start time. In return, the city exempted deliveries of hot asphalt, wet concrete, and structural steel from a set of complementary regulations intended to reduce the number of heavy-duty trucks traveling on city streets during peak hours. The negotiations involved numerous stakeholders, including the Associated General Contractors of California, the California Building Industry Association, the Southern California Ready Mixed Concrete Association, the L.A. County Building and Construction Trades Council, and other local union groups (Reinhold, 1989).

Other states have recognized that construction during peak hours contributes to congestion and have sought various ways to mitigate this problem. Few, however, have gone as far as banning construction during certain hours, probably due to resistance from the construction industry. For instance, Ohio—home to the fourth-largest interstate network in the country and carrying the fifth-largest volume of traffic—has implemented a maintenance-of-traffic policy stating that engineers should incorporate traffic planning as part of the overall project design so that solutions to avoid increased congestion are in place before a project begins. Banning construction during the peak hours, though, is not mandated (Grant, 2000).

To the extent that rush-hour construction bans slow development activities, some developers may oppose such rules as well.

General Political Obstacles

Rating: Low. Voters are likely to support a rush-hour construction ban, since it will ease the commuting experience. Other than potential pressure from the construction and development industries just described, elected officials would have little reason to oppose such policies.

Institutional Obstacles

Rating: Low. Effective rush-hour construction bans may require the cooperation of transportation, public works, and law-enforcement agencies. Fortunately, these often fall under the same jurisdiction, which will tend to reduce the level of institutional obstacles.

While transportation departments will often manage road maintenance and improvement activities, public-works departments may need to disturb roads in order to gain access to underground water, gas, and electrical lines. Construction bans will typically affect these activities as well, and this can be problematic if the intended public-works project is important for public safety and health. Accordingly, peak-hour construction bans such as the one recently implemented in Los Angeles will often include exemptions allowing critical public-works projects to be completed as swiftly as possible. Such exemptions prevent what might otherwise arise as an institutional conflict between the missions of a transportation department and a public-works department.

The participation of law enforcement is important to ensure that bans on any construction activities not exempted are strictly enforced, especially lane closures that might result from private real estate–development activities adjacent to the roadway. Absent enforcement, such bans may simply be ignored (Fine, 2005).

Current Status in the L.A. Region

Rating: Moderate. While the City of Los Angeles has implemented a peak-hour construction ban, many other cities in the county do not have such rules in place. We therefore rate the current status of this strategy in the L.A. region as *moderate*.

During Mayor Tom Bradley's tenure in office, Los Angeles passed a law requiring all major construction activities in Los Angeles to shift

work hours from 7:00 a.m.–4:00 p.m. to 6:00 a.m.–3:00 p.m., becoming the first city in the nation to require an earlier start for construction work. A major goal of this policy was to shift the time at which 30,000 trucks run by the construction firms and 125,000 cars driven by employees would travel to and from work sites each day, thus reducing peak-hour traffic for other commuters. The movement of heavy-duty trucks providing a steady stream of supply deliveries to the work sites also added to congestion. This policy of shifting construction activities to an earlier time frame was part of a broader plan to bar 70 percent of heavy-duty trucks from the city streets during peak hours, requiring many goods to be delivered at night (Reinhold, 1989).

More recently, Mayor Villaraigosa's office has estimated that poorly scheduled maintenance and repair projects account for about 15 percent of all traffic delays (L.A. Office of the Mayor, undated). To address this problem, Mayor Villaraigosa implemented a construction ban during rush hours in August 2005. The ban prohibits rush-hour construction by city departments and agencies as well as by noncity entities except under specific exemptions. Under the new policy, rush-hour work is defined as actual construction, as well as the staging of equipment and materials, on major roads from 6:00 a.m. to 9:00 a.m. and 3:00 p.m. to 7:00 p.m. Exemptions are provided for emergency work related to public health and safety as well as for major public-works projects associated with traffic-mitigation plans, and guidelines for evaluating exemption petitions have been developed (BOE, 2006). Although the law was implemented in August 2005, L.A. residents have recently complained of insufficient enforcement (Office of Jack Weiss, 2007).

Interaction with Other Strategies

In addition to making travel faster and safer for drivers, rush-hour construction bans are likely to do the same for other modes, including transit (see Appendix B25), walking (see Appendix B27), and cycling (see Appendix B28).

Incident-Management Systems

Traffic congestion can be divided into two broad categories: recurrent and nonrecurrent. Recurrent congestion, typically associated with peak-hour travel periods, occurs on roads and highways where the demand for travel routinely exceeds a facility's capacity and is relatively predictable. Nonrecurrent congestion occurs as a result of traffic incidents—including accidents, running out of fuel, flat tires, mechanical difficulties, and spilled truck loads—as well as other factors, such as special events, severe weather, construction, or road repairs that slow traffic. Traffic incidents can contribute to congestion directly by blocking one or more lanes, thereby reducing a facility's capacity. Additionally, even traffic incidents that occur on the side of the road can stimulate the phenomenon of rubbernecking, in which motorists slow down to look more closely as they pass. The overall contribution of incident-related congestion to traveler delays varies from one location to the next, but most analysts agree that it represents a significant share. Downs (2004), for instance, reviewed data suggesting that traffic incidents account, on average, for about 60 percent of peak-hour congestion in urban areas. Skabardonis et al. (1998) estimated that traffic incidents are responsible for 61 percent of all traffic congestion and that about 50 percent of motorist delays on the freeway are incident related.

The term *incident management* refers to strategies that attempt to reduce the total duration of traffic incidents, thereby reducing nonrecurrent-congestion delays. Given the significant share of overall congestion caused by traffic incidents, successful incident-management programs can have a significant effect in reducing traffic delays. Key

elements of incident-management programs include incident detection, verification, response, and clearance (Skabardonis et al., 1998).

Methods of detecting and verifying incidents include the following:

- mobile-telephone calls from motorists
- CCTV cameras viewed by operators
- electronic traffic-measuring devices (e.g., video imaging, loop or radar detectors)
- automatic vehicle identification (AVI) and detection software
- motorist-aid telephones or call boxes
- police patrols
- aerial surveillance
- transportation or public-works crews reporting via two-way radio
- service patrols (Ozbay et al., 2005).

Once an incident has been detected and verified, the next steps are to respond and clear the incident as quickly as possible. This may involve assistance—such as providing fuel or helping with a flat tire—that allows motorists to drive away on their own, or it may require towing a car to another location. Depending on the severity, emergency medical care—and perhaps even accident-scene investigation services—may also be required. While incident response and clearing efforts are still under way, information alerting other drivers of the incident, and perhaps suggesting alternative travel routes, can be broadcast via radio or displayed on variable-message signs (VMSs). The full set of resources that may be of use in incident response and clearing activities includes the following:

- computer-aided dispatch systems
- service-patrol fleets
- towing and recovery vehicles
- law-enforcement fleets
- fire engines
- rescue units and ambulances

- major incident–response teams
- changeable message signs
- hazardous material–response units
- arterial-signal controllers (Ozbay et al., 2005).

Cities throughout the United States have implemented a wide range of strategies for incident management. The Hoosier Helper program in Indiana, for example, deploys existing police-patrol units to high-incident freeway sections (Latoski, Pal, and Sinha, 1999). In Maryland, the incident-response strategy includes interdisciplinary teams (involving transportation, law enforcement, and emergency medical professionals) trained in handling large or more severe incidents on the freeway. Their job is to respond quickly, to set up an incident-management command post, to determine the severity of the incident, to call in appropriate help from experts, and to contact persons who control special equipment that may be required. They typically coordinate the efforts of all responding agencies (Ozbay et al., 2005).

As an alternative to reliance on law enforcement, jurisdictions can establish FSP programs that deploy tow-truck drivers to patrol freeways in order to help stranded motorists, remove traffic accidents, and keep traffic moving. FSP programs have already been established in many states, such as California, Colorado, Georgia, Illinois, Maryland, Michigan, Minnesota, New Jersey, New York, North Carolina, Texas, and Washington. The size of these FSP programs varies considerably, ranging from just a couple of tow trucks in some cities to about 150 in L.A. County (Pal and Sinha, 2000).

An incident-management system for L.A. County was first developed in the early 1970s. In 1991, the system was augmented with the start of the FSP program—one of the first of its kind in the United States. There are currently 13 major metropolitan FSP programs in California, and the L.A. County program is the largest of these. The service is provided at no charge to users.

Evaluation of Strategy

Cost/Revenue Implications

Rating: Medium cost. As outlined previously, the key tasks of an incident-management system, include detecting, verifying, responding to, and clearing incidents. Many of the strategies for detecting and verifying incidents involve such technologies as loop detectors, CCTV cameras and camera towers, and call boxes. Depending on the specific options selected, such technologies can cost thousands or even tens of thousands of dollars per unit.¹ If such technologies are deployed throughout the entire freeway or arterial network, the capital costs can become quite large. Many of these technologies require ongoing maintenance (and associated costs) as well. Interestingly, the use of cell phones—which can also be used to report incidents with a high level of effectiveness (for instance, stranded motorists can use their own cell phones to call for help, or passing motorists can alert authorities to disabled vehicles)—requires no investment on the part of local or state governments (Ozby et al., 2005).

In terms of responding to and clearing incidents, a larger share of the expense involves ongoing operating costs—for example, paying tow-truck drivers to patrol the freeway system. The costs for FSP programs depend largely on the size of the tow-truck fleet, the hours of operation, and the miles of freeway patrolled. For the relatively small Hoosier Helper program in northwest Indiana, the daytime operating costs were just \$411,000 per year in 1995 (Latoski, Pal, and Sinha, 1999). In comparison, the annual budget for the much larger L.A. County FSP was \$24 million in 1996. During that year, the Los Angeles FSP program included 149 trucks divided among 40 beats (or patrol routes), which covered 404 centerline miles of the county's freeway system. The average cost per hour per beat was \$146.25, while the average cost per tow truck per hour was \$40.63. The benefit/cost ratio was estimated at more than 5 to 1 (Skabardonis et al., 1998). The L.A. County FSP program remains ongoing, although the number of trucks and beats and

¹ See Ozby et al. (2005) for cost-estimate ranges for various detection and verification options.

the amount of freeway mileage covered have not increased much in the intervening years. Note that a side benefit of the FSP program in Los Angeles is that it can lower costs for CHP by reducing the number of freeway incidents to which CHP must respond.

Short-Term Effectiveness in Reducing Congestion

Rating: High. Incident management does not entirely eliminate congestion, but it can reduce the duration of congestion that an incident causes, especially minor incidents. This is an important advantage, as the vast majority of incidents are minor rather than major. Downs (2004), for example, cited data suggesting that disabled vehicles—not accidents or other, more-severe problems—cause about 80 percent of traffic-delaying incidents.

Supporting this observation, a recent study of Minnesota's FSP program found that 88 percent of the reported incidents examined were relatively minor, impeding traffic flow for a period of 27 minutes or less. Among this group, the incidents that received FSP assistance were cleared, on average, in just four minutes. In contrast, the average clearing time was about 12 minutes for incidents that did not receive such assistance. About 9 percent of the incidents reported during the study were more severe in nature. Of these, the average clearing time for incidents that received FSP assistance was 35 minutes, while the average clearing time for those that did not was about 40 minutes. In short, the Minnesota FSP program proved useful for all incident categories, but the greatest benefit—both in the number of incidents served and the reduction in the time required to clear the incidents—occurred with minor incidents (MNDOT, 2004).

In another study that focused on one beat in the L.A. County FSP program, the majority of reported incidents were also minor, with just 6.5 percent of the incidents involving accidents. The study authors estimated that the L.A. County FSP program reduced incident-response and clearing time by around 15 minutes on average (Skabardonis et al., 1998). The FSP studies of Minnesota and L.A. County suggest that significant reductions in incident-related congestion can be achieved with tow-truck assistance alone. Only a minority of incidents involve

severe accidents that require participation from multiple responders and result in longer incident duration.

A study of Maryland's FSP program provides additional evidence of the benefits of aggressive incident-response efforts. Researchers estimated that the Maryland program reduced the average incident duration by 57 percent in 2000 and by 55 percent in 1999 and that the program reduced aggregate travel delay on the freeway system by 15.6 million vehicle hours in 1997 (Ozby et al., 2005).

Long-Term Effectiveness in Reducing Congestion

Rating: Low. To the extent that incident-management systems succeed in reducing nonrecurrent congestion on the freeway or arterial systems during peak hours, travelers will observe that traffic appears to be flowing more smoothly. Under the phenomenon of triple convergence, they may therefore begin to make more automotive trips during peak hours, thereby eroding some of the traffic improvements yielded through incident management. In other words, nonrecurrent congestion will be reduced, while the level of recurring congestion will rise in response. This constrains the potential of incident-management strategies to achieve lasting long-term congestion relief during peak hours.

Mobility, Accessibility, and Traveler Choice

Rating: Good. By reducing nonrecurring congestion, incident-management strategies enable existing roads to carry more vehicles per lane-mile per hour. This boosts net mobility among drivers. If buses use the same facilities, such strategies may lead to improvements in mobility and traveler choice among transit users as well.

Safety

Rating: Very good. Traffic incidents often lead to secondary accidents. For one thing, passing drivers may become distracted by looking at the incident and crash into one another (i.e., a secondary crash). The stranded driver is also in harm's way from oncoming traffic. While remaining in the stalled car may be safer than standing in the open roadway, the driver's well-being is still at risk. Getting disabled vehicles

and their drivers off the highways as quickly as possible is therefore quite important from a safety perspective.

While data indicate a fairly wide range in observed secondary-crash rates, most evidence suggests that such crashes represent a considerable portion of all traffic accidents. Estimates of the rate of secondary crashes as a percent of all crashes range from 1.5 percent on L.A. freeways (Moore, Giuliano, and Cho, 2004) to 35 percent on freeways in Gary, Indiana (MNDOT, 2004), though some of this variation may be due to a lack of consensus on the definition of a secondary crash. According to FHWA (2002), secondary crashes account for between 14 and 18 percent of all crashes and have been estimated to cause 18 percent of all deaths on the freeways. A study of Minnesota freeways estimated that 15 percent of all crashes were secondary crashes (MNDOT, 2004). On a 24-mile stretch of the Frank Borman Expressway in Gary, Indiana, 35 percent of all crashes occurring between 1992 and 1995 were of a secondary nature (Karlaftis et al., 1998).

Most analysts agree that incident-management strategies, by clearing disabled vehicles more quickly, can help reduce the incidence of secondary crashes. While the precise effects can be difficult to quantify, efforts to estimate secondary-incident reduction resulting from various incident-management strategies have been reported in the literature. In Pennsylvania, the Traffic and Incident Management System was estimated to reduce secondary crashes on highways by 40 percent between 1993 and 1997. In San Antonio, the TransGuide system, equipped with lane-control signs, loop detectors, CCTV, VMSs, and a communication network covering 26 instrumented miles, reduced secondary crashes by about 30 percent in 1995. In Amsterdam, a traffic-management system comprising loop detectors, video cameras, VMSs, lane controls, and variable speed limits decreased secondary crashes by around 46 percent (USDOT ITS, undated). A study of Highway 401 in Toronto showed that the application of VMS technology reduced the secondary-crash rate from 16.8 percent to just 5.2 percent (Delcan Corporation, 1994). Analysis of the Maryland program also demonstrated that effective incident management can reduce the number of secondary accidents that occur as traffic slows—often abruptly—when approaching the site of the primary incident. Based on Maryland State

Police accident reports, researchers estimated that Maryland's FSP program, by clearing incidents more quickly, results in a reduction of about 350 secondary accidents each year (Ozby et al., 2005).

Economic Efficiency

Rating: Very good. Incident-management systems can be viewed as promoting greater economic efficiency from two perspectives. First, by reducing nonrecurrent congestion, they boost the effective capacity of the existing road network, yielding greater productivity from existing investments in transportation infrastructure.

Second, incident-management systems appear to be quite cost-effective when examined in terms of quantifiable benefits, although there is considerable variation in the range of benefit/cost ratios that have been reported. Estimates of the benefit/cost ratio for FSP programs range from 3.4 to 1 in San Francisco to 36 to 1 in Houston (MNDOT, 2004). The benefit/cost ratio of the L.A. FSP program was calculated to be at least 5 to 1 (Skabardonis et al., 1998). To illustrate how these calculations are performed, consider the Hoosier Helper FSP program in northwest Indiana, where the benefit/cost ratio for daytime operations was estimated at 4.7 to 1 in 1995. The annual cost of operating the program during daytime hours was \$411,000, while the benefits were estimated at \$2 million—including \$1.2 million in travel-time savings through the reduction of nonrecurrent congestion, \$78,000 in reduced vehicle-operating costs, and \$600,000 due to a reduction in secondary crashes. Comparing \$2 million in benefits to \$411,000 in costs results in a benefit/cost ratio of 4.7 to 1 (Latoski, Pal, and Sinha, 1999).

Environment

Rating: Very good. Using tow trucks to patrol the road network does result in additional oil consumption, air pollutants, and greenhouse-gas emissions. These effects are swamped, however, by the savings that can be achieved by reducing the number of hours that cars spend idling in nonrecurrent, incident-related congestion.

As an example, it was estimated that the southeast Michigan FSP program led to a reduction of about 11.7 million vehicle hours of delay

on freeways in the service region in 2006. This improvement resulted in *daily* reductions of about 2,100 kilograms (kg) of volatile organic compounds, 1,000 kg of nitrogen oxides, and 15,600 kg of carbon-monoxide pollutants (SEMCOG, 2007). Another study examined the results of the Minnesota FSP program for May 2003. The findings of this study indicated that the FSP program led to a savings, in just one month, of 55,000 gallons of fuel, 22.5 tons of carbon monoxide, 0.4 tons of hydrocarbons, and 1.2 tons of nitrogen (MNDOT, 2004).

Equity

Rating: Good. Lower-income drivers have less disposable income to purchase newer and more reliable vehicles and pay for routine maintenance, so they may be more likely to experience such problems as breakdowns, flat tires, and the like. As a result, incident-management programs that assist disabled vehicles can be especially beneficial for lower-income groups as a whole. As an additional observation, the study by Skabardonis et al. (1998) reported that FSP tow-truck drivers detected about 85 percent of the incidents assisted by the L.A. FSP program, while CHP detected another 13 percent. As a result, lack of access to a cell phone—which is also more likely among lower-income drivers—did not prevent access to roadside assistance.

The benefits of reductions in nonrecurrent delays on the road network accrue to all drivers—wealthy or poor. Since wealthier individuals drive, on average, more than poorer individuals, they could be expected to receive a larger share of these benefits. Lower-income drivers are still better off, however, than they would be in the absence of incident-management systems.

Stakeholder Concerns

Rating: Low. Tow-truck companies not involved in providing FSP may argue that such programs cut into their business. The L.A. County FSP program, however, currently uses an open-bid system to hire tow-truck services. The open-bid system should reduce the potential for dissent, since all tow-truck companies have the same opportunity to bid.

Private mechanic shops might also raise concerns of unfair treatment based on the potential for tow-truck drivers to form agreements

under which they would receive commission in return for towing the cars to certain mechanic shops. The L.A. County FSP program does not allow tow-truck drivers to recommend a mechanic shop, though, which reduces the potential for such behavior.

General Political Obstacles

Rating: Low. On average, L.A. County FSP serves about 300,000 motorists per year. Responses to surveys filled out by L.A. motorists who had received FSP assistance indicate that more than 93 percent rate the service as excellent and a worthwhile expenditure of public funds. In 1990, L.A. County voters approved Proposition C for transportation improvements, including incident-management programs. The program also receives federal funds, state funds, and other local funds, indicating broad support at all levels of government (Skabardonis et al., 1998).

Institutional Obstacles

Rating: Medium/can fully address—>low. Depending on their scope and complexity, incident-management systems can require coordination and cooperation across different types of agencies (e.g., transportation and emergency response), across multiple jurisdictions (e.g., adjacent cities or counties), or across multiple levels of government. But the existence of successful programs in many cities shows that these challenges can be overcome. Houston's incident-management program, for instance, provides an example of a successful partnership involving the Texas Department of Transportation, the Metropolitan Transit Authority of Harris County, and the City of Houston. The program involves both transportation and emergency-management agencies, combining resources across functional and jurisdictional boundaries. In 1997, the program saved an estimated 2.7 million vehicle hours of delay, and, by 2004, the annual savings in delay had grown to about 12.7 million vehicle hours. Houston's program uses a three-tiered management structure with representation from each of the participating agencies on each committee (TTI, 2005).

Similarly, numerous agencies cooperate in the L.A. County FPS program, including CHP, Caltrans, Metro, medical responders, fire

departments, auto clubs, and private tow-truck drivers. To achieve the most efficient response procedure, all must work together. A study sponsored by FHWA (Hawkins et al., 2006) recommended the development of a comprehensive, integrated accident-response plan—one that addresses strategic and institutional questions as well as tactical issues at the scene of the incident. At the tactical end of the spectrum, the plan should be quite specific, providing concrete instructions on such issues as the proper deployment of various responders (CHP, fire-department trucks, emergency ambulances, and tow trucks) around the scene of the incident. The study further suggested that a hierarchy of command with clearly defined roles for all involved would result in the safest and most expedient clearing of incidents. As part of the response team, one person should be designated as the traffic-control lead. That person's role involves directing the flow of passing traffic, but there should also be guidelines on how to alert drivers of likely delays, preplanned diversion routes, and variable speed limits as a means of slowing upstream traffic.

It should be noted that the role of law-enforcement agencies, such as CHP, is critical not only in managing incidents but in preventing many crashes in the first place. In particular, the visual presence of CHP helps promote traffic safety by serving as an effective deterrent to unsafe driving. However, the extent of proactive patrolling by CHP has declined markedly in the past few years, and the number of traffic accidents has increased correspondingly (Steenhausen, 2005).

Current Status in the L.A. Region

Rating: Moderate. L.A. County has a very advanced incident-management program for freeway operations. The City of Los Angeles has pilot-tested an incident-response program for the arterial system, but, to date, this concept has not been implemented at full scale. For this reason, we rate the current status in Los Angeles as *moderate*—representing a blend of advanced implementation on the freeway system and limited implementation elsewhere.

The county's freeway incident-management system, initiated by CHP and Caltrans in the 1970s, is one of the most advanced in the nation. Beginning with a Caltrans-operated surveillance and control

system that covered 41 miles of the freeway system, the system has expanded to cover more than 400 miles of freeways throughout the county. Technical components include ramp meters, loop detectors, VMSs, and cameras linked to a CCTV system. In July 1991, the program was expanded to include an FSP component. CHP has statutory responsibility under this program for overall management at the site of all freeway incidents, and Caltrans is responsible for system traffic control during major incidents and for maintenance support. To streamline operations, the decision was made to contract with the private towing industry, which provides towing services under the direction of CHP (Ozbay et al., 2005).

L.A. County's FSP program, with 149 service trucks, is the largest fleet in the country and patrols 444 miles of L.A. County freeways. Each FSP tow truck is equipped with a dedicated communication system that links the Caltrans and CHP communication centers, including voice radio equipment, mobile digital-data systems for two-way nonvoice communication, and an automatic vehicle-location system that enables both Caltrans and CHP dispatchers to determine the location of all tow trucks at all times during Metro FSP operations. These trucks patrol designated portions of freeways, referred to as *beats*, during the morning and afternoon commute hours. Each beat is about 10 miles long, and three to five trucks are assigned to each beat. There are 43 beats in total. FSP operates on every freeway in L.A. County from 6:00 a.m. to 7:00 p.m. on weekdays and from 10:00 a.m. to 6:30 p.m. on weekends (Metro, undated[b]). The program has proven to be extremely cost-effective, and it is believed that the competitive bidding process for the private provision of towing services leads to greater efficiency than would be possible with state-operated tow trucks (Ozbay et al., 2005).

This FSP service is funded by Proposition C and is free to users. Drivers can call #399 from their cell phones to request FSP assistance, report freeway road hazards, contact an auto club, or report freeway damage or needed repairs. The call center is staffed by English and Spanish speakers, can provide translation in more than 150 languages, and is equipped to serve people with hearing or speech impairments. About 70 percent of those assisted wait less than five minutes before

an FSP truck arrives. In about four out of five assists, FSP drivers can repair the problem at the scene within 10 minutes of arriving (Metro, undated[b]).

To evaluate the effectiveness of the L.A. FSP program, a 7.8-mile section of the I-10 freeway (beat 8) in Los Angeles was examined in the late 1990s. During the course of the study, a total of 1,560 incidents were observed, averaging about 41 peak-hour incidents per day. Of these, FSP provided assistance to 1,035 incidents, about two-thirds of the total. Just 6.5 percent of the observed incidents were due to accidents, and just 10 percent of the observed incidents blocked a traffic lane. The average duration of all incidents was 19.8 minutes, and the FSP program reduced the average time needed to clear the incident by an estimated 15 minutes. With an annual budget of \$24 million in 1998, the benefit/cost ratio was calculated to exceed a 5 to 1 ratio (Skabardonis et al., 1998).

More recently, LADOT piloted a rapid-response team, one that is modeled after FSP but applied on congested city arterial routes (Jeff, 2006a). Detailed results of the pilot test were not available as of this writing.

Interaction with Other Strategies

Successful incident-management programs can help boost the effectiveness of HOV lanes or shared HOV/bus lanes (see Appendix B3). Many of the HOV lanes in L.A. County are currently operating at more than 70-percent capacity. A survey of HOV users found that savings in travel time was the biggest factor in their decision to change their mode of travel to higher-occupancy vehicles in order to access HOV lanes (Parsons Brinckerhoff, 2002). The rapid clearing of incidents on HOV lanes is critical to maintaining adequate flow, which, in turn, is critical to encouraging carpooling and transit ridership.

Intelligent transportation systems (ITSs) can be integrated to better manage incident-response logistics. Major incidents can engage multiple actors, including the police, the fire department, traffic-control centers, paramedics, towing companies, and the media. Efficient and effective coordination of these actors in a dynamic, time-pressured environment is essential to shortening the incident-response and clear-

ing time. ITS-enabled decision-support systems may help coordinate such an effort (Zografos, Androutsopoulos, and Vasilakis, 2000).

ITS deployment can also help other drivers avoid incidents. A study of Chicago commuters showed that, given information about an incident, many drivers choose to divert from their normal route in order to avoid incident-related traffic. According to the study, drivers were more willing to divert if the congestion was caused by incidents (as opposed to normal recurring congestion), if the information was received from radio traffic reports rather than personal observation and if the trip direction was home to work rather than work to home. Furthermore, commuters were less willing to divert if their alternative route was unfamiliar or unsafe or had several traffic stops (Khattak, Koppelman, and Schofer, 1993). Given these findings, real-time information about incident delays passed on to drivers through highway-advisory radio stations, VMSs, personal digital assistants, or cell phones may help mitigate incident-induced congestion and may reduce secondary accidents.

Ride-Sharing

The terms *carpooling* and *vanpooling*—collectively known as *ride-sharing*—describe driving with multiple passengers, as opposed to driving in an SOV. Many transportation experts look at the unoccupied seats in SOVs as the greatest underutilized resource in transportation. Carpooling is generally more prevalent for nonwork trips—for example, family members driving together to run errands or friends driving together to go out for dinner. As a share of commute trips nationally, carpooling has generally declined and now stands at approximately 12 percent (Pisarski, 2006).

Many provisions, which vary in degree of public and private investment, can encourage ride-sharing:

- *Preferred parking for carpools or vanpools:* Ride-share vehicles can be given more desirable parking spots, guaranteed parking, or free parking in situations in which other parking is paid. This generally works best when parking can be monitored in some way—for example, an employer with a guarded lot. Employers, especially those with fewer spaces than employees, often use this strategy.
- *Carpool and vanpool rider-matching services:* Often referred to as *ride-matching*, carpool and vanpool matching provides a service through which potential ride-sharers can meet others with similar commutes. While large employers or building owners can accomplish this, it is more commonly implemented through regional programs that match people based on home and work location. New software programs allow instant matching online, whereas prior programs required potential ride-sharers to wait for matches.

Once individuals are matched, they can then work out a mutually convenient schedule.

- *Dynamic ride-matching*: In addition to conventional, regionally based ride-matching programs, which typically result in quasi-permanent ride-share arrangements, another possibility is to perform instant matching for one-time trips. This practice is often described as *dynamic ride-matching*. One private-sector organization, NuRide (undated), currently provides such instant matching, with the goal of allowing people to carpool on an occasional basis. However, many people likely still use the service for commuting. NuRide has established a network in several East Coast and Midwest cities but does not currently operate in Southern California. The company provides incentives to users, in the form of gift certificates from corporate sponsors. In some regions, NuRide has also partnered with transportation agencies.
- *Casual carpooling*: A more informal type of carpooling, often described as *casual carpooling*, has become popular in several regions across the country, including the San Francisco Bay Area, Houston, and Washington, D.C. To gain access to HOV lanes and avoid tolls within these regions, single drivers pick up passengers who wait at designated pickup sites, often at park-and-ride lots or along transit routes, and bring them to designated drop-off points, generally in CBDs or other high-employment areas. The number of passengers that a driver will pick up depends on HOV restrictions; in the San Francisco Bay Area, for example, commuters from the East Bay need three people in a vehicle to avoid the James “Sunny Jim” Rolph Bridge (a.k.a. Bay Bridge) tolls (and backups at the toll plaza). Drivers and passengers who participate in casual carpooling generally agree to a few rules, which tend to be self-enforced (see, for example, Forel Publishing Company, 2008), and safety has not proven to be a major issue with these informal programs.
- *Vanpooling programs*: Vanpooling is like carpooling, but it involves larger vehicles and often a more formal structure. Vanpool programs can be privately or publicly operated; private operators can include individuals, employers, and companies specializing in

vanpools. One important distinction is that qualified vanpools, unlike typical carpools, are eligible for commuter benefits, which reduce federal and, in some cases, state taxes for drivers and riders. Vanpools are more commonly associated with employer sites and often serve just a single work site. Employers can establish their own vanpools or work with a third-party provider. In some regions, local governments operate and subsidize vanpools.

- *HOV lanes:* While HOV lanes are discussed as a separate strategy elsewhere in this document (see Appendix B3), the presence of such facilities can make it easier to encourage ride-sharing. It serves as a time incentive and, in some cases, a financial incentive not to drive alone.

Evaluation of Strategy

Note that ride-sharing programs are often voluntary or incentive-based, and our evaluation of the strategy assumes that this is the case. It is also possible, however, that building owners and managers or large employers could be mandated to implement trip-reduction programs, which certainly could include ride-sharing options as one element of a more comprehensive set of options. We discuss this potential application of ride-sharing separately as part of the mandatory-TDM-program strategy assessment (see Appendix B16).

Cost/Revenue Implications

Rating: Low cost. Since HOV infrastructure is discussed elsewhere, this section assesses other means to increase ride-sharing. Capital costs to promote ride-sharing might include new or enhanced software to increase the speed and accuracy of matches, or start-up costs to assist private organizations (such as NuRide) in establishing themselves in the market. A public vanpool program would include vehicle costs for vans. If a casual carpooling program were to be encouraged, the public sector might provide park-and-ride lots and signage.

In terms of operating costs, as noted, promoting ride-sharing should be seen as an ongoing effort, which includes operating costs for

salaries, updates to ride-matching software, and marketing expenses. If the region were to begin operating vanpools, there would be operating costs, such as vehicle maintenance, fuel, and insurance, as well as outreach to encourage its use. Most regional commuter-assistance programs incur annual operating expenses in the range of a few million dollars; however, these include outreach for all types of TDM programs, not just for ride-sharing.

Carpooling and vanpooling do not generally produce public revenue, unless a public agency operates a vanpooling program and charges riders.

Short-Term Effectiveness in Reducing Congestion

Rating: Low. Carpooling and vanpooling have been falling as a share of overall commute trips nationwide, and Southern California is no exception. According to SCAG's *State of the Commute Report 2006* (the most recent available), the carpooling share for commuting was 12.2 percent as of 2005; this represents a decrease from a high of 15.6 percent in 1995. Vanpooling comprises just 0.6 percent of the region's commute mode share, from a high in 1997 of 1.2 percent (SCAG, 2006). Nationwide, the highest share of carpooling occurred in 1980, when it reached a level of 20 percent (Pisarski, 2006).

Ride-sharing can probably make a moderate difference in corridors with HOV lanes and in high-employment areas that attract many commute trips during peak hours. One strategy might be to work with employers to provide carpooling incentives, such as preferred parking or reward programs. These programs might be effective for employers with constrained parking. There may be some effective strategies for event-based ride-sharing, such as off-site parking for major sporting or entertainment events. Finally, it might be possible to encourage casual carpooling in some of the HOV lanes in the region.

Few regions attempt to measure the performance of their ride-sharing programs, since multiple factors unrelated to the efforts of commuter-assistance organizations (such as the price of gas or changes in residential or workplace location) affect participation. The agency that does the most thorough assessment, the Metropolitan Washington (D.C.) Council of Governments, found that, for fiscal years 2003 to

2005, the integrated ride-sharing program (consisting of online ride-matching and kiosks throughout the region), resulted in a reduction of 5,500 trips and 146,000 VMT per day (LDA Consulting, 2006).

Long-Term Effectiveness in Reducing Congestion

Rating: Low. In the long run, increased ride-sharing will probably not have a major effect on reducing traffic. To begin with, like most other strategies, ride-sharing is subject to the effects of triple convergence; if more people begin to ride-share and this reduces the ambient level of congestion, the combined influence of latent and induced demand may quickly reclaim the temporarily freed road capacity.

In addition, it is simply difficult to increase ride-sharing in a multicentric region, since no single area commands a sizable share of area employment. Also, carpooling and vanpooling are not effective strategies for noncommute trips; carpooling, as noted, is already prevalent for many nonwork trips, and it may be close to its upper limit for such trips.

Some of the commonly cited barriers to carpooling and vanpooling include need for access to a vehicle during the workday or before or after work for other trips, difficulty finding people with whom to share rides (due to not living and working in close proximity or not having similar work hours), and privacy.

Given that people are constantly moving in and out of the region or changing jobs and that employment sites are constantly changing, marketing carpooling and vanpooling must be viewed as an ongoing enterprise, rather than a one-time investment.

Mobility, Accessibility, and Traveler Choice

Rating: Good. Carpooling and vanpooling can increase mobility for members of households without vehicles. Ride-sharing also offers the opportunity for individuals to reduce the costs associated with owning and operating their own vehicle.

Safety

Rating: Neutral. Carpooling carries essentially the same safety risks as driving alone. While figures for vanpool crashes per million

miles traveled were not immediately available, since 1990, only three fatalities have been reported nationwide in vanpool crashes (BTS, 2007a).

Economic Efficiency

Rating: Good. A mode shift to increased ride-sharing would have a positive effect on economic efficiency in that it promotes more-efficient use of existing infrastructure. Ride-sharing makes use of what would otherwise have been unused capacity in vehicles.

Environment

Rating: Good. Increased ride-sharing would have some impact on emissions—both criteria pollutants and greenhouse gases—depending on the magnitude of the mode shift. If participants drive alone to a meeting spot and then vanpool together, this may cut into those reductions, as reductions depend in part on the number of trips reduced, not only the amount of VMT reduced.

Equity

Rating: Good. Ride-sharing can improve equity for low-income households and individuals who do not own an automobile by lowering commuting expenses and providing additional transportation options. Equity could be improved by providing bilingual outreach staff and materials to ensure that non-English speakers have equal access to such programs. Nationwide, the rate of Latino carpooling is double that for whites, indicating that this may be a good market for encouraging ride-sharing (Pisarski, 2006).

Stakeholder Concerns

Rating: Low. Carpooling and vanpooling are typically voluntary programs, and, as a result, stakeholder opposition is likely to be *low*. Transit operators may have some opposition to casual carpooling, perhaps arguing that casual carpoolers would otherwise be riding transit.

General Political Obstacles

Rating: Low. Carpooling via employer-based programs and ride-matching is already being promoted in the region and is generally not controversial. It might be more controversial to provide start-up funding for a private firm, given limited resources, or to begin a public van-pooling program when many are already operating privately.

Institutional Obstacles

Rating: Medium/difficult to mitigate—>medium. Some efforts are ongoing, with multiple jurisdictions involved through CommuteSmart, a service operated by Riverside County in conjunction with the transportation agencies of Los Angeles, Orange, San Bernardino, and Ventura Counties (CommuteSmart, undated[a]). Regional outreach efforts are generally easier if requirements and incentives are standard across jurisdictional boundaries. For example, western Riverside and San Bernardino counties have incentive programs for carpoolers, but other counties do not. Employer outreach can be complicated if incentives and assistance vary among cities and counties, since many employers have multiple sites. While this study examined congestion in Los Angeles, the city forms part of a complex region with many commute flows across city and county boundaries, and some amount of L.A. congestion is due to residents of other areas entering Los Angeles for work or other reasons.

Promoting ride-sharing should not require state or federal involvement. If the region operates vanpools, state insurance regulations may play a role in the program's structure.

Current Status in the L.A. Region

Rating: Moderate. As mentioned, CommuteSmart already provides regional ride-matching. The current system uses Trapeze RidePro software, which provides instant online ride-matching. While the database of interested ride-sharers is smaller than the database compiled using the previous software, it is more accurate and the percentage of people who successfully find matches is similar (Stark, 2007).

Metro has operated the Metro Vanpool Program since April 2007. Participating vanpools can receive a monthly subsidy of up to \$400 or

half the lease costs of the van. Vanpools must be formed through one of three leasing partners (VPSI, Enterprise Rent-a-Car Company, and Midway Auto Group), be filled to at least 70-percent occupancy, be open to any member of the public wishing to join, and serve a work site in L.A. County. CommuteSmart assists commuters with vanpool formation and ride-matching but does not operate or pay for vanpooling. Currently, 430 vanpools participate; the goal is to reach 1,000 after several years (Stark, 2007). The overall placement rate (the proportion of commuters who received assistance from Metro's commuter-service group and changed their travel behavior) is 8 percent, which includes the following:

- 1.6-percent continued placement rate
- 1.1-percent temporary placement rate
- 5.3-percent one-time placement rate (Stark, 2007).

Employers with more than 250 employees at a single work site must comply with AQMD Rule 2202 (AQMD, 2004), which requires employers to either offer programs to offset commute-related emissions or pay into a regional fund for emission-reduction programs. If employers choose the former, they must meet a target average vehicle ridership (AVR)¹ or continue to add programs to increase AVR. Employers can use support for carpooling and vanpooling as one of their strategies to increase AVR. Approximately 200 of the 720 work sites participating in this program meet their AVR target, which can vary from 1.3 in suburban areas to 1.75 in downtown Los Angeles (Gomez and Thomas, 2007).

L.A. County has 425 miles of HOV lanes, which are also open to ultralow-emission vehicles. HOV requirements are enforced 24 hours per day. Casual carpooling is not established in the region.

¹ AVR is calculated as the number of employees divided by the number of vehicles entering a work site between the hours of 6:00 a.m. and 10:00 a.m. For example, if 500 employees arrive in that period, along with a total of 300 vehicles (which may include some single drivers along with some carpools), AVR is calculated as 1.67 (500/300) regardless of the split between single drivers, carpools, and other modes.

Interaction with Other Strategies

Ride-sharing promotion fits well with HOV-lane strategies (see Appendix B3), because these provide a time benefit for ride-sharing. They would also dovetail well with more controversial strategies for reducing driving—such as HOT lanes (see Appendix B18), cordon congestion tolls (see Appendix B19), variable curb-parking rates (see Appendix B20), or mandated driving restrictions (see Appendix B17)—as they could help mitigate some of the equity and stakeholder concerns associated with such programs. Finally, carpools and vanpools can benefit from park-and-ride lots (see Appendix B4) that provide a meeting point for riders.

Telecommuting

The term *telecommuting* refers to conducting work from a location other than an employee's usual work site: from home, from a satellite office, or from the road. It generally relies on information technology (IT) infrastructure to allow the employee access to colleagues and information. Sometimes *telecommuting* is distinguished from *telework*, which refers to any work done from home that uses IT for face-to-face contact, but the two terms are often used interchangeably.

Individual employers implement telecommuting, although a few states and regions have incentive programs to encourage wider adoption of telecommuting. Not every employer is able to adopt telecommuting; much depends on the type of work, the composition of the workforce, the level of available IT infrastructure, and information or other security issues that could preclude employees from working offsite.

While most telecommuting is done from employees' homes, some regions have established telecommuting centers where employees from multiple employers can have access to IT infrastructure, such as computers and high-speed or wireless Internet service; office equipment, such as copiers and fax machines; and support personnel. The Washington, D.C., region, for example, has 16 such telecommuting centers.

One advantage in persuading employers to adopt telecommuting is that, in some fields, it has become an accepted part of benefits packages, and many new hires have come to expect that the ability to telecommute, at least part time, will be a condition of employment. Some employers operate very formal telecommuting programs, while others allow it on a casual or case-by-case basis. Some employers that have

adopted telecommuting tout other benefits as well, such as increased productivity and decreased costs for parking or office space.

On the other hand, a drawback for telecommuting as a congestion-reduction strategy is that many telecommuters work from home only one or two days per week. Any estimate of the potential to reduce congestion should take this into account and not assume that telecommuting will constitute a full-time change in commute patterns for all telecommuting employees. Also, even if telecommuters do not make a work trip, they may engage in additional nonwork trips, which could reduce the potential traffic benefits. Finally, if telecommuters use a telecommuting center rather than working from home, they may reduce their VMT but still take the same number of trips.

Evaluation of Strategy

Note that the implementation of telecommuting programs among employers is typically voluntary or incentive-based, and our evaluation of the strategy assumes that this is the case. It is also possible, however, that large employers could be mandated to implement trip-reduction programs, which might include telecommuting as one element of a more comprehensive set of options. We discuss this potential application of telecommuting separately as part of the mandatory-TDM-program strategy assessment (see Appendix B16).

Cost/Revenue Implications

Rating: Low cost. The required public investment to set up an outreach program to encourage employers to implement telecommuting is not likely to be significant. Setting up regional telecommuting centers, on the other hand, probably represents a moderate capital investment. One report recommended at least three years of public funding for a center to establish itself. Estimated start-up costs (in 2000 dollars) are \$500,000, plus operating costs of \$18,000 per month, for a public investment of \$1.15 million (Bacharach and Siembab, 2005).

Similar to capital costs, the level of operating costs depends on whether the program is strictly outreach or includes establishing cen-

ters. Operating costs for centers would include rent for the space, staff support, marketing and outreach, equipment leasing or maintenance, and other upkeep (e.g., janitorial service).

This takes into account only the public-sector costs. An estimate by JALA International (2008), a telecommuting consulting firm, put an estimate of the employer cost to establish a telecommuting program for its employees at around \$3,000 in one-time costs and \$1,000 in recurring costs. If a public-sector program were to provide incentives to defray those costs, that would constitute an additional operating cost. The Telework!VA program, operated by the Virginia Department of Rail and Public Transportation, offers to reimburse qualified employers up to \$35,000, provided that their resulting telecommuting program meets certain benchmarks (DRPT, undated).

Telecommuting would not result in public revenues unless telecommuting centers were operated on a fee-for-service basis. In the JALA estimate, a center would need to include 60 workstations, charge \$590 per month for each, and operate at 90-percent capacity to break even (Bacharach and Siembab, 2005).

Short-Term Effectiveness in Reducing Congestion

Rating: Low. While telecommuting leads to a reduction in trips and VMT, the traffic impacts are generally small due to the relatively low number of telecommuters as a percentage of the workforce combined with the low number of days telecommuted. Even significant increases in the percentage of telecommuting would therefore likely have at most a modest effect on traffic congestion. The studies, based on several telecommuting pilot projects in California, show the range of travel behavior changes:

- In a pilot program conducted by the City of Los Angeles, 441 telecommuters received training and 203 were still active at the end of the program. An evaluation of the pilot found that, on average, telecommuters worked from home 4.2 days per month during the first year and eight days per month at two years. Telecommuting employees had commutes of similar length to nontelecommuters (22.8 miles and 23.1 miles, respectively). The study also found

that, on average, there was no increase in vehicle use for nonwork trips (i.e., the VMT saved by telecommuting were not used on other trips) (Nilles, 1993).

- In the California Neighborhood Telecenters project, all but one of the telecommuting centers received substantial public funding as a TDM measure. Between 1991 and 1997, 45 centers opened, and 22 of those subsequently closed (17 of the original centers were in L.A. County, and seven of those closed). The main reason for closing was an inability to become financially self-sufficient, whether due to inadequate business planning or insufficient usage (almost all charged user fees to recoup their costs). The centers that remained operational had generally branched into services, such as distance learning, training, and e-commerce, as well as retaining ongoing support from a public-sector partner (Buckinger et al., 1997). An early review of these telecommuting centers found that daily vehicle trips among telecommuters actually increased by one on days when people telecommuted from a center, mostly because they drove home for lunch. However, VMT declined by 65 percent, or 38 miles per day. When adjusted by the number of days telecommuted, the overall reduction in VMT among the telecommuters was 17 percent. Telecommuters were also more likely to drive alone to the telecommuting center than to their usual work site (Balepur, Varma, and Mokhtarian, 1998).
- An analysis of 1991 California data comparing home-based telecommuters and commuting workers found that the telecommuters and commuters made the same number of trips but that the telecommuters traveled approximately half the amount of VMT (Mokhtarian and Henderson, 1998).
- A study of more-recent L.A. data from the eCommute pilot program found that telecommuters worked from home, on average, between one and two days per week, and the average round-trip commute distance was 67 miles. While this was based on data collected over several years (the pilot was in place from 2001 to 2004), the study included only 31 telecommuters from the region (Walls and Nelson, 2004).

Telecommuting promotion in other regions has been a mixed success. The Commuter Connections program in the Washington, D.C., region has an ongoing effort to promote telecommuting, including telecommuting centers, regional advertising on telecommuting, seminars, and an information kit. This program has resulted in an estimated reduction of 11,000 trips and 227,000 VMT per day. However, an expansion of the program did not reach its goals. The program, the expanded version of which lasted for two years (2003 to 2005), included outreach to more than 800 large employers and free provision of technical assistance to establish or expand telecommuting programs. According to an evaluation, instead of the 113,000 anticipated telecommuters, only 4,884 began telecommuting, and the daily VMT reduction was only 37,000, instead of the hoped-for 303,000. The evaluation suggested several reasons for the program's failure to meet its goals, including the difficulty of working with large employers (for example, hierarchies and multiple locations meant longer decision-making) and optimistic assumptions about telecommuting frequency and effects. For example, previous surveys had shown that most telecommuters work away from their office less than 1.5 days per week, but this program's goal was higher. Similarly, 26 percent of telecommuters used non-SOV modes on days they went to their offices, so these did not count as trips or VMT eliminated (Ramfos and Albiero, 2006).

Long-Term Effectiveness in Reducing Congestion

Rating: Low. Like many other of the strategies considered in this study, any traffic reductions achieved through telecommuting are subject to erosion as a result of triple convergence, which limits telecommuting's long-term effectiveness in achieving significant traffic reductions. In addition, even when people switch to telecommuting, they generally do not do so every day, for a variety of reasons. Also, depending on the nature of the areas to be targeted for congestion relief, there may be limited opportunities for telecommuting (for example, service jobs at such work sites as restaurants and hotels are not amenable to telecommuting). A fuller evaluation of the potential for telecommuting in the region would involve a closer look at the labor market in and around Los Angeles to determine the proportion of jobs suitable for

telecommuting. According to an analysis for SCAG, for telecommuting to reach the goal of eliminating 5.6 percent of all trips, either the number of telecommuters would need to increase to 30 percent of all employees or the number of days on which current telecommuters telecommuted would have to increase (LDA Consulting, 2003).

It is difficult to say what mode share telecommuting makes up in the United States or whether it is increasing, since multiple information sources offer widely varying estimates. According to *Commuting in America* (Pisarski, 2006), which tracks commuting trends based on U.S. census data, telecommuting has increased from just over 2 percent in 1980 (just over 2 million employees) to just over 3 percent in 2000 (about 4 million employees) (Pisarski, 2006). The American Housing Survey found 4.8 million telecommuters in 1995 and 5.7 million in 1997. According to the Bureau of Labor Statistics, telecommuting declined from 3.6 million in 1997 to 3.4 million in 2001. Private market-research data suggest higher numbers, but surveys are based on small sample sizes, nonrandom samples, and wider definitions of *home-based work* (Mokhtarian, Choo, and Salomon, 2005). On a nationwide basis, the long-term reduction in VMT from telecommuting has been estimated at less than 1 percent (Choo, Mokhtarian, and Salomon, 2005).

Mobility, Accessibility, and Traveler Choice

Rating: Good. The ability to telecommute gives employees additional choice about where to spend their workdays.

Safety

Rating: Good. To the extent that telecommuting would remove vehicles from the road during congested periods, the number of crashes would likely be reduced.

Economic Efficiency

Rating: Good. Telecommuting's effects on employee productivity are not clear, but there are other positive (but modest) effects. To the extent that telecommuting allows the same amount of productivity while reducing travel, it can be said to utilize existing infrastruc-

ture more efficiently. Advocates of telecommuting also claim that it can be an effective provision to keep businesses running after an attack or natural disaster (which was, in fact, the case after the Northridge earthquake).

Environment

Rating: Good. Increased telecommuting would have some impact on emissions—both criteria pollutants and greenhouse gases—depending on the magnitude of the mode shift. If telecommuters drive alone to telecommuting centers, VMT may be lower but the number of trips the same.

Equity

Rating: Neutral. Telecommuting would not have a negative impact on lower-income workers; for the most part, it would probably make no difference to this group. The types of jobs more amenable to telecommuting tend to be higher-paying, white-collar jobs. Some lower-income workers may be able to telecommute (for example, data entry might be performed from home). Telecommuting would have a positive impact on those workers, but the overall benefits would likely be minimal.

Stakeholder Concerns

Rating: Low. The business community, which would implement telecommuting for individual employers, would be the main stakeholder on this issue. Unless telecommuting were made mandatory (at the employer or employee level), it is not expected that individual employers would object to public technical assistance or incentives to encourage telecommuting.

General Political Obstacles

Rating: Low. With the exception of the possible negative perceptions of focusing on a strategy aimed at white-collar employment, no constituency is against telecommuting. Some surveys have shown great interest among nontelecommuters to begin telecommuting. There might be more opposition to public funding of telecommuting centers, depending on the cost.

Institutional Obstacles

Rating: Low. Providing telecommuting assistance does not require as much regional cooperation as do other TDM strategies, such as carpooling or commuter benefits, since the issues that employers face in creating a telecommuting program do not vary as much from work site to work site. Setting up telecommuting centers would require more cooperation, and implementing a regionwide incentive program would probably require the highest degree. Such incentives could be implemented locally or by the state, which would presumably require legislation.

Current Status in the L.A. Region

Rating: Moderate. Southern California was a leader in promoting telecommuting in the 1990s and early 2000s. The City of Los Angeles Telecommuting Pilot Project ran from 1990 to 1992 and allowed more than 400 city employees to try telecommuting. The Southern California Emergency Telecommuting Partnership was formed as a public-private partnership after the Northridge earthquake of 1994. From 1991 to 1997, Caltrans and FHWA funded the Residential Area-Based Offices (RABO) project (also known as the California Neighborhood Telecenters Project) to assess the potential for telecommuting centers. Finally, the region was one of five to participate in the federal eCommute program from 2001 to 2004, which tracked emissions that were saved by telecommuting in order to test the theory that emission credits might be traded. However, the partnership, RABO, and eCommute are no longer operational. Metro promotes telecommuting and provides some employer assistance, but there is no large-scale regional promotion of telecommuting.

The number of telecommuting centers has also been declining. Twenty were operating in 1995, serving 100,000 employees; many of these were established after the 1994 Northridge earthquake (Kaplan, 1995). By 2001, there were just five (SCAG, 2001).

A report prepared for Ventura County (Bacharach and Siembab, 2005) made the following observations:

- Southern California was a national leader in the 1990s, although most regions developed some type of telework initiative. AQMD and Metro invested at least \$10 million in shared work facilities. The city and county of Los Angeles conducted high-profile work-at-home programs.
- As we look back, the various initiatives can be seen to have either failed or achieved limited success and have mostly been terminated. Home-based telecommuting continues in many corporations but often informally. However, the failures were of execution rather than of concept. And there were enough successes on which an interested region could build.

According to SCAG's 2006 *State of the Commute Report*, 14 percent of workers in L.A. County have the opportunity to telecommute. Of those with the opportunity, 79 percent actually telecommute (meaning that, in total, 11 percent of employees telecommute). On a regionwide basis, the average number of days telecommuting is 4.8 per month. The sample size was too small to analyze the number of days worked at home by county (SCAG, 2006).

Interaction with Other Strategies

Telecommuting is a valuable complement to strategies that use pricing to reduce automotive-travel demand, such as local fuel taxes (see Appendix B22) and cordon congestion tolls (see Appendix B19). Specifically, telecommuting provides another option for employees to avoid driving to work, at least on some days, thereby allowing them to save money.

Flexible Work Hours

The term *flextime*, also referred to as *alternative work schedules* or *variable work hours*, is used to describe programs that enable employees to vary the hours or days on which they work, provided that they still meet the employer's requirements (i.e., a certain number of hours per week). There are several common forms of flextime. One is the compressed workweek, in which employees work fewer but longer days. For example, employees might work four 10-hour days each week, or they might work five nine-hour days one week and four the next. Another form of flextime is staggered shifts, in which employees have the opportunity to select from a predefined set of shift options. Some shifts, for instance, may run from 8:00 a.m. to 4:30 p.m., others from 8:30 a.m. to 5:00 p.m., and others from 9:00 a.m. to 5:30 p.m. Finally, the most flexible form allows employees to come and go whenever they choose as long as they meet the employer's requirements. This tends to be more common for jobs that require comparatively little interaction with other employees or clients throughout the day, such as computer programming or data analysis. Flextime programs are often implemented to provide employees with a greater level of convenience, but one of the side benefits of flextime is the ability to help reduce congestion during peak travel periods.

Evaluation of Strategy

Currently, most flextime programs are voluntary; that is, employers are not required to offer flextime alternatives to their employees but

may do so if they wish. The ratings presented here assume that these programs remain voluntary. It is certainly possible, however, that regulations could be imposed that would require employers to reduce peak-hour vehicle-commute trips, in which case flextime might be one of a suite of strategies that employers could apply to meet the requirements. We discuss this potential application of flexible work hours separately as part of the mandatory-TDM-program strategy assessment (see Appendix B16).

Cost/Revenue Implications

Rating: Low cost. The cost of implementing flextime programs tends to be quite low. From the public perspective, the main expenses might include educational outreach efforts to inform employers of the benefits of flextime and encourage them to allow it where possible. Note that public agencies can—and often do—provide certain forms of flextime for their own employees without incurring significant additional costs.

Short-Term Effectiveness in Reducing Congestion

Rating: Medium. Studies suggest that flextime programs are successful in reducing peak-hour commutes, though the effect on overall driving behavior is somewhat unclear. Cervero and Griesenbeck (1988) examined the effectiveness of flextime programs used by firms in Pleasanton, California, a rapidly growing suburb of the San Francisco Bay Area. By analyzing traffic flows into and out of Pleasanton, the authors determined that flextime programs have the effect of spreading commute trips over a broader range of hours, thereby reducing peak flows. They also observed a slight rise in the level of solo driving, suggesting that flextime programs may make ride-sharing more difficult. A subsequent study by Freas and Anderson (1991) produced additional evidence that flextime programs can reduce peak-period congestion. In this case, however, the authors argued that flextime programs can actually increase the feasibility of transit use and ride-sharing. With transit, for example, the buses or trains may be less crowded—and therefore more comfortable—during the off-peak hours, and it may be easier to use transit when work schedules can be aligned with transit-

route schedules. With less pressure to arrive at work at a specific time, employees may also have greater flexibility to arrange for carpooling. A study by Ewing (1993) estimated that flextime programs result in a 20- to 50-percent reduction in peak-period commuting among employees with access to flextime options, but Ewing observed little overall effect on solo driving. Finally, a more recent study by Picado (2000) found that employees with flexible work schedules save an average of seven minutes per day in commute time.

Long-Term Effectiveness in Reducing Congestion

Rating: Low. The congestion-relief benefits of flextime programs are likely to be lower over the longer term. To begin with, any gains produced by the strategy will slowly erode due to the effects of triple convergence. In addition, even if flextime programs become more widespread over time, many employees will be unwilling or unable to take advantage of the opportunity to shift their commute times, whether due to personal preferences or the need to match travel schedules with other family members (e.g., dropping children off at school). In one study, for example, only 20 percent of the surveyed employees with flextime options chose to shift their commute times to avoid congestion (Picado, 2000).

Mobility, Accessibility, and Traveler Choice

Rating: Good. First and foremost, flextime provides employees with the opportunity to choose their own commute times. As argued in the preceding section, this may, in turn, expand their ability to choose other modes of travel, such as public transit. In addition, if flextime programs lead to initial traffic reductions during the peak periods, then the additional freed road space may, in turn, serve other automotive trips that would not otherwise occur. These additional trips—the results of latent demand and triple convergence—may erode any initial traffic-relief gains, but they still contribute to a net increase in social mobility across different modes and different times of day. On balance, then, it should be expected that flextime would offer benefits in terms of mobility, accessibility, and traveler choice.

Safety

Rating: Bad/difficult to mitigate—>bad. Flextime programs will initially shift some auto commute trips from peak to off-peak hours. Over time, however, through the effects of triple convergence and latent demand, additional peak-hour auto trips will slowly fill any temporarily freed capacity in the peak hours. As a result, net automotive travel is likely to increase, resulting in additional collisions.

Economic Efficiency

Rating: Neutral. The potential effects of flextime programs on economic efficiency are mixed. On the one hand, flextime enables employees to travel during off-peak periods, thereby reducing unnecessary commuting delays. It may also enable them to address other scheduling demands, such as dropping off children or running errands, with greater ease and efficiency. On the other hand, if a greater percentage of employees begin and end their workdays at different times, it can become more difficult to coordinate group schedules and meeting times, potentially introducing workplace inefficiencies. From a broader social perspective, these two effects should at least partially cancel out one another, leading to our rating of *neutral*.

Environment

Rating: Bad/difficult to mitigate—>bad. As argued in the previous section, flextime programs, combined with the effects of latent demand and triple convergence, will, over time, lead to net increases in total travel (more traffic in the off-peak hours and similar levels of traffic during the peaks). This, in turn, will increase the level of emissions for criteria pollutants as well as greenhouse gases.

Equity

Rating: Good. Many workers who face economic, physical, or family-related challenges may place a particularly high value on work-time flexibility, and, from that perspective, flextime programs offer the potential for modest equity benefits. For example, single parents may find it much easier to address child-care responsibilities if they can vary their work schedules as needed. That said, it should be noted that

many jobs at the lower end of the pay scale—such as in the service or manufacturing industries—may be less amenable to flextime options. Even so, the institution of flextime policies where possible does not adversely effect those employees without access to flextime; rather, it adds benefits for those employees who do qualify, and this will make life easier for at least some members of society who are economically disadvantaged or face other challenges.

Stakeholder Concerns

Rating: Low. Because employers' implementation of flextime policies is optional, stakeholder opposition is unlikely.

General Political Obstacles

Rating: Low. General political obstacles are also unlikely, given the voluntary nature of flextime programs.

Institutional Obstacles

Rating: Low. Though the public sector can certainly play a role in promoting flextime, implementation is the responsibility of individual employers. Institutional obstacles, therefore, are not likely to materialize.

Current Status in the L.A. Region

Rating: Significant. Currently, flextime and other alternative work schedules are implemented throughout the L.A. region. Because employees value the ability to work flexible hours, many firms that are able (given the nature of their industry) to implement flextime policies have already taken this step. While some firms in the region may not yet offer flextime but could do so, the overall prospects for increasing flextime options in private industry are likely limited.

Interaction with Other Strategies

Flextime policies should work effectively with—or at least not contradict—a range of other traffic-relief strategies. They are especially valuable, however, in combination with programs that involve some form of peak-period-travel pricing—such as HOT lanes (see Appen-

dix B18), cordon congestion tolls (see Appendix B19), or variable transit fares (see Appendix B23). By enabling off-peak commutes, flextime programs provide employees with the option of driving or taking transit when tolls or fares are lower.

One strategy with which flextime policies may not work effectively is ride-sharing (see Appendix B11). As the variability in work start and end times increase, it may become more difficult for individual employees to find ride-sharing partners. That said, the evidence from existing studies on this issue is somewhat mixed. As mentioned earlier, Cervero and Griesenbeck (1988) found that flextime programs led to an increase in SOV driving (and therefore, likely, a reduction in ride-sharing), whereas the study by Freas and Anderson (1991) suggested that flextime programs could actually make it easier to engage in ride-sharing.

Car-Sharing

Car-sharing—not to be confused with carpooling, vanpooling, or ride-sharing—refers to short-term vehicle rentals by organization members who pay by the hour. For convenience, vehicles are scattered at parking sites in residential neighborhoods or commercial areas, and reservations can be made online or via telephone. Members also have access to a variety of vehicles, including hybrids and trucks.

The primary advantage of car-sharing is that it allows people to avoid the significant fixed costs of vehicle ownership—such as the purchase price, maintenance, and insurance—and use a car only when necessary. This is accomplished by establishing an hourly charge for car-sharing, generally in the range of \$8 to \$11, that reflects the full set of costs of owning and operating a vehicle. The hourly rate is higher than the marginal cost paid by most vehicle owners (e.g., buying fuel), for whom the costs of ownership and insurance are paid in advance. From the perspective of traffic relief, this is an important distinction. Because car-sharing members face higher marginal costs for vehicle use, they have a stronger incentive to reduce their automotive travel by choosing other modes when possible. If a large percentage of drivers in a region were to elect car-sharing in place of private vehicle ownership, total vehicle travel, and, in turn, the level of congestion, could, in theory, be reduced, at least to some extent.

Car-sharing has been ongoing in Europe for several decades and was introduced into the U.S. market in the 1990s. There are several for-profit car-sharing companies operating in multiple cities, along

with other local not-for-profit organizations.¹ Nationwide, car-sharing membership has been estimated at approximately 75,000 people sharing about 1,200 vehicles in 17 programs as of 2005 (Shaheen, Cohen, and Roberts, 2006). Membership is generally marketed to people who drive fewer than 10,000 miles per year and people who do not drive to work. Car-sharing also tends to work best in neighborhoods of higher densities, where there are more potential users for every vehicle and where it is possible to walk, bike, or use transit for a larger percentage of trips (such that members do not find it necessary to own a vehicle).

While car-sharing operates successfully in some cities as a private business, there can be public-sector involvement in making parking spaces available. This can provide an important boost to car-sharing operations, as the provision of convenient vehicle locations is often a major selling point for a program; ideally, members can walk just a few blocks to an available vehicle. In some areas, such as Arlington, Virginia, the local transportation agency has made dedicated on-street parking available. Other jurisdictions have encouraged private developers to include car-sharing spaces in multifamily housing. For example, a Parking and Transportation Demand Management ordinance in Cambridge, Massachusetts, requires reducing parking demand in buildings with 20 or more spaces; one of the ways in which developers can meet this requirement is by providing dedicated car-sharing spaces. In Vancouver, British Columbia, the municipal code allows developers to substitute one car-sharing space for three regular parking spaces (Millard-Ball et al., 2005).

Car-sharing in the United States was initially launched and marketed as a service for individuals, but some car-sharing organizations have discovered that businesses are interested in providing membership for their employees as well. Many commuters drive to work at least in part because they will need the vehicle for additional trips at some point during the day. Because car-sharing programs provide vehicles that employees can use as needed once they have arrived at work, they may help reduce the number of commuters who drive to work each

¹ Note that, in October 2007, the two main for-profit car-sharing operators, Zipcar and Flexcar, announced plans to merge (Zipcar, 2007).

day. Car-sharing programs can also be used as a way for businesses to outsource fleet management.²

Evaluation of Strategy

Cost/Revenue Implications

Rating: Low cost. Car-sharing programs are usually operated by private firms that bear the majority of capital and operating costs, such as vehicle acquisition, maintenance, and storage. The most common form of public assistance is providing parking spaces for car-sharing vehicles. In the L.A. market, where Flexcar operated (and now Zipcar operates) a car-sharing program, the public sector might make in-kind donations of public parking spaces or dedicate on-street parking for shared vehicles. The public costs would then consist of any forgone revenues that result from taking these spaces out of the inventory of paid parking (assuming that they were metered or otherwise paid to begin with). Note that, in some cities, such as Boston, parking spaces have been allocated to car-sharing programs without cost for the first year or two, but the charges for using the spaces have gradually been raised back up to the prevailing rate.

Short-Term Effectiveness in Reducing Congestion

Rating: Negligible. Car-sharing has been shown to have some impact on auto ownership and travel behavior among members. According to one report that reviewed a number of studies, car-sharing reduces vehicle ownership (on average, every shared car replaces five or six privately owned vehicles) as well as VMT (in four studies reviewed, VMT decreased between 18 and 46 percent, although, in some cases, the results were not considered statistically significant). There is also some evidence that VMT by members who had not previously owned a car rose considerably, although not to the same level as that for members who had previously owned vehicles (Millard-Ball et al., 2005).

² See testimonial from Zipcar business users (Zipcar, undated).

Despite the potential for stimulating reductions in driving, car-sharing will probably not lead to any appreciable level of traffic relief in the short term. The main reason is that the current number of members in the L.A. region (just under 2,000, out of millions of drivers) is far too small to produce a measurable decrease in congestion. Even significant percentage gains in membership over the next several years would pale in comparison to the continued growth in privately owned vehicles.

Long-Term Effectiveness in Reducing Congestion

Rating: Low. In the longer term, aggressive expansion of car-sharing in Los Angeles could help reduce congestion to some degree, though the effects would still likely be modest. To begin with, as mentioned in the preceding section, car-sharing membership is still in its infancy. If the number of car-sharing patrons in Los Angeles were to double each year for the next five years, there would still be only 60,000 members out of a population that numbers in the millions. (By comparison, the world's largest car-sharing operation, in Switzerland, has approximately 73,000 members after 10 years in operation.) It will take a number of years, therefore, before car-sharing can achieve significant market penetration. Second, many of the individuals who have joined car-sharing operations did not previously commute to work in private automobiles, so the effects on traffic reduction during peak commute hours would tend to be limited. Third, any reductions in traffic that do result from car-sharing programs would be, like many other strategies discussed in this document, subject to the phenomenon of triple convergence, through which latent and induced demand would slowly erode any congestion-reduction benefits. All that said, there still could be a slight positive effect in neighborhoods with a very high concentration of shared cars, including busy commercial districts.

Mobility, Accessibility, and Traveler Choice

Rating: Very good. Car-sharing can enhance mobility for people who did not previously have access to a car. Instead of being limited to destinations accessible only via transit, bicycle, or walking, members can gain access to other areas as well by using one of the shared vehi-

cles when needed. In addition, car-sharing programs offer a money-saving option for individuals who currently own seldom-used vehicles, enabling them to sell those vehicles (or, in some cases, to sell a second vehicle that is not used as often as the primary vehicle) and rely on a shared car instead.

An additional benefit of car-sharing is the potential for reducing the number of parking spaces required for some types of development, which, in turn, can help promote more-compact urban form and greater housing affordability. For example, developers of multifamily rental housing might provide parking for shared cars while reducing parking for privately owned vehicles, thereby lowering a project's overall construction costs. The individual parking spaces could then be unbundled from the price of leasing a unit—that is, rented separately from the housing unit. This would allow a family to reduce its monthly expenses by \$100 or \$200 simply by choosing not to rent one of the individually paid parking spaces (or perhaps by choosing to rent just one rather than two spaces). Because the development also provides on-site car-sharing, the family would not need to sacrifice its mobility to achieve this greater level of housing affordability.

Safety

Rating: Neutral. Car-sharing carries essentially the same safety risks as driving alone. To the extent that car-sharing reduces vehicle trips, it would also reduce the number of vehicular accidents. On the other hand, if reducing the number of driving trips leads to more walking and bicycling trips, the accident rates for those modes could increase. On the whole, however, the aggregate effects on travel safety are likely to be negligible.

Economic Efficiency

Rating: Good. Car-sharing promotes economic efficiency in several ways. First, it enables multiple individuals to share a vehicle, thereby getting more use out of a capital investment. Second, it converts many of the fixed costs associated with automobile ownership—such as the purchase price, insurance, and routine maintenance—into variable costs that must be paid each time a vehicle is used. This provides a

financial incentive for individuals to drive only when the benefits that they receive from a trip outweigh the full private costs of making the trip. Third, as noted in the previous section, car-sharing can facilitate more-efficient use of parking resources, which, in turn, can reduce construction costs and promote greater housing affordability.

Environment

Rating: Good. Both criteria pollutants and greenhouse gases would be reduced in connection with a reduction in VMT and trips; however, given the current size of the car-sharing market, the impacts would be modest at best.

Equity

Rating: Neutral (uncertain). Demographic analysis shows that most current car-sharing members tend to be well educated (with a college or postgraduate degree), more affluent than nonmembers, and from a small household (one or two people). One survey of members of nine car-sharing organizations in North America found that 87 percent of respondents were white (Millard-Ball et al., 2005). Therefore, under most forms of car-sharing, we expect impacts on lower-income households to be neutral, as the prevalence of car-sharing among higher-income groups would neither help nor hurt them.

However, some cities have instituted programs to make car-sharing available to low-income households as a mobility measure. The San Francisco Bay Area Metropolitan Transportation Commission, for example, subsidized low-income residents in two San Francisco neighborhoods with deposit waivers and reductions in hourly rates (Millard-Ball et al., 2005). In addition, car-sharing services could be provided at large multifamily housing developments to help promote greater housing affordability, as described earlier. Such applications would provide added mobility to low-income households. Because of this potential, we describe the equity effects of car-sharing as *good* but also *uncertain*.

Stakeholder Concerns

Rating: Low. If employers or developers were required to provide parking spaces for car-sharing and reduce the number of other park-

ing spaces accordingly, many would probably object. It is much more likely, however, that this concept would be presented as an option for developers or employers to consider, and, in this case, there should not be any significant stakeholder concerns.

General Political Obstacles

Rating: Low. No constituency is against car-sharing. If public parking spaces are dedicated to car-sharing, there may be some complaints. However, parking is not as scarce in Los Angeles as it is in other cities with car-sharing, and they have not experienced political resistance. It would likely not be an issue in Los Angeles either.

Institutional Obstacles

Rating: Low. Car-sharing already exists across multiple cities in the L.A. region. Unlike other TDM measures that require extensive public outreach and benefit from regional coordination, any public-sector assistance is invisible to car-sharing members because the car-sharing organization spans the region. Even if another car-sharing company were to open in Los Angeles (several cities in the United States have two operators), this would not raise jurisdictional hurdles.

Current Status in the L.A. Region

Rating: Limited. As of August 2007, Zipcar, a for-profit car-sharing firm, operated in the L.A. area with 47 vehicles in and around downtown Los Angeles; 17 at the University of California, Los Angeles (UCLA), eight at the University of Southern California; five in Pasadena; five at Wilshire Center; four in Hollywood; four in Santa Monica; and two in Venice, for a total of 92 vehicles. The fleet includes cars, light trucks, and hybrid vehicles. Flexcar established itself in the region in 2003 and saw a 50-percent increase in usage in the first half of 2007. Zipcar currently has 1,850 members in the region, and staff members report that interest is very high. Zipcar was able to enroll members in Hollywood even before vehicles were placed there, in anticipation of their arrival (Kemp, 2007).

According to Zipcar staff, a main challenge has been explaining to the public how car-sharing operates, but, with marketing, the con-

cept has gained increasing traction. Also, most vehicles are currently stored in private lots when not in use, but Zipcar hopes to work with the City of Los Angeles to provide spaces in public lots (Kemp, 2007). According to one report, Metro has provided some assistance to Zipcar in the form of office space and has provided it with marketing materials along with its own materials at transportation events (Millard-Ball et al., 2005).

Interaction with Other Strategies

Car-sharing at work sites could complement efforts to encourage employees not to drive alone, such as ride-sharing initiatives (see Appendix B11) or employer parking cash-out (see Appendix B21), since the practice provides vehicle access during the workday.

Traveler-Information Systems

The purpose of traveler-information systems is to provide information about highway and arterial street conditions and transit schedules to help travelers make decisions about the best routes, times, and travel modes for their trips. Armed with such information, travelers can avoid making trips at the most congested times of the day or on the most congested corridors in the network. Traveler-information systems can also provide travel-time estimations based on current conditions, thus reducing the stress associated with unpredictable travel conditions resulting from congestion and traffic incidents. Information provided to motorists can include traffic-condition reports, suggested alternative routes, estimated travel times, and alerts related to incidents, construction activity, or road closures. Information for transit users can include transit-schedule changes, unexpected delays, and next-bus (or next-train) arrival times. The information provided by these systems can be useful in planning a trip (e.g., selecting the best route, time, or mode of travel) or during the trip itself (e.g., selecting an alternative route in the event of traffic accidents or road closures).

Information for motorists can be conveyed in a number of ways:

- *Radio messages:* These messages, broadcast through local radio stations, typically provide information on the current state of the road network, including alerts about traffic incidents and areas of heavy congestion. The timeliness of information through this channel can vary (Homburger et al., 2007).
- *VMSs:* These signs, posted along the road network (most commonly on freeways), can provide travel-time estimates, traveler

alerts, suggested route alternatives, and other forms of traffic advisories. Because signs are placed in specific locations, the information they convey can be tailored to travelers along different routes (Margulici et al., 2006).

- *Trip-planning systems:* These rely on a backbone of ITS technology that monitors, communicates, and processes data on road and traffic conditions. The data are then relayed to travelers via Internet, television broadcast, telephone, and interactive, computer-based kiosks (Papacostas and Prevedouros, 2001). A well-known example is the 511 system. In 2000, the Federal Communications Commission designated 511 as a dedicated three-digit national telephone number for traveler information. Where 511 systems have been implemented, travelers can obtain real-time information from an automated telephone system about local transit schedules, freeway and arterial road conditions, ride-sharing options, and expected travel times. With any trip-planning system, however, conditions along the route of travel can change by the time the trip is under way, and this may undermine the utility of such services (Lyons and McDonald, 1998).
- *In-vehicle guidance systems:* Also referred to as *advanced traveler information systems*, these systems rely on GPS devices to monitor current vehicle location, compute suggested travel routes, and provide computerized map displays. These systems also have the potential to use real-time information to optimize and customize route planning, though this additional functionality is not always available, depending on the service provider. Although in-vehicle guidance systems are privately owned, installed, and operated in individual vehicles, any real-time information used by these systems in the United States is typically collected and provided by public-sector agencies (Kanninen, 1996).

The majority of states and regions in the United States provide some form of real-time traffic information through radio, television, Internet, and 511 services. Notable examples include the Caltrans Smart-Traveler system, TravTek in Orlando, Advance Chicago, and FAST-TRAC in Michigan (Zhang and Levinson, 2006). A 2004 survey

found that 41 states in the country have deployed traveler-information Web sites, 25 offer highway-advisory radio services, and eight provide statewide or regional 511 systems (USDOT ITS, 2008). As of December 2007, there were 41 active 511 systems in the United States (511 Deployment Coalition, 2008).

Evaluation of Strategy

The following evaluation focuses on information systems targeted toward motorists rather than transit users. When transit information is provided for congestion-management purposes, the intention is to make transit more convenient and thus to encourage drivers to change modes; the effectiveness of transit information in reducing congestion is therefore considered separately under the strategy evaluation for BRT features (see Appendix B25).

Cost/Revenue Implications

Rating: Medium cost (uncertain). The cost of implementing and maintaining traveler-information systems can vary depending on system type and combination of features. On the high end of the spectrum, 511 systems require costly surveillance, communications, and centralized management systems, and these can be very expensive. Such infrastructure can also support other transportation-management systems, such as ramp metering, traffic-signal timing, and traffic-incident detection and response. The costs of implementing traveler-information systems will thus depend to a large degree on whether the necessary underlying infrastructure is already in place. For this reason, we describe our rating of *medium cost* as being *uncertain*.

Once the necessary supporting infrastructure is in place, additional 511 system-development costs are reported to range from just over \$100,000 to just over \$1,000,000 (averaging a bit more than \$400,000), while ongoing operation costs range from \$0.10 to just under \$3 per call handled by the system (511 Deployment Coalition, 2004). Operating costs include labor, equipment, information and content upgrades, telecommunications, and marketing.

Although the potential for revenue collection (e.g., charging for telephone- or Web-based information or for customized subscription services) exists, evidence is mixed on users' willingness to pay. According to one study (Fekpe and Collins, 2003), just 10 percent of travelers who used Web-based, real-time information systems in Pittsburgh and about 27 percent of system users in Philadelphia indicated a willingness to pay for traffic information. Another study found that, while 35 percent of the staff surveyed at the University of Minnesota expressed a willingness to pay for private traveler-information services, 70 percent of the sample considered the public sector as the most appropriate provider of free information (Zhang and Levinson, 2006).

Short-Term Effectiveness in Reducing Congestion

Rating: Low (uncertain). To the extent that traveler-information systems can motivate motorists to travel on alternative routes or during alternative times (or forgo travel altogether), this strategy can help manage congestion in the short term. However, information provision may produce other outcomes depending on the number of travelers who receive the information, how they react to the information, and the availability of alternatives. Several studies have suggested that, when travelers learn of congested conditions, the majority of them may choose to postpone their trips but cause congestion when they later enter the transportation network (Arnott, de Palma, and Lindsey, 1991; Ben-Akiva, de Palma, and Kaysi, 1996). These studies suggest that benefits are highest when information is provided to only a few drivers; some models have even shown that, when all drivers are informed, travel times may actually *increase* (Arnott, de Palma, and Lindsey, 1991; Al-Deek, Khatkhat, and Thananjeyan, 1998).

Additionally, the extent of travel-time savings may depend less on the provision of information than on the availability of noncongested alternatives. Traffic diversion away from congested areas may produce little relief when the alternatives are also congested (Al-Deek and Kanafani, 1993). In general, findings suggest that the effectiveness of traveler-information systems depends on users' responses, information accuracy, the customization of information, the percentage of informed drivers, the availability of alternative routes, the levels and

types of congestion, and the magnitude of induced demand (Zhang and Levinson, 2006). For this reason, traveler-information systems are rated as having *low*—but *uncertain*—effects in reducing congestion in the short term.

Long-Term Effectiveness in Reducing Congestion

Rating: Low. The effectiveness of traveler-information systems in stemming longer-term growth in congestion is also likely to be *low*. With continuing growth in the population and economy, traveler-information systems will do little to reduce the aggregate demand for travel. Moreover, the effects of triple convergence are likely to erode any shorter-term congestion-reduction benefits that might result from the use of traveler-information systems.

Mobility, Accessibility, and Traveler Choice

Rating: Very good. To the extent that traveler-information systems do reduce congestion, they will enhance overall mobility. More importantly for this rating, however, is that they play a strong role in enhancing traveler choice. Specifically, the information provided through such systems enables travelers to make more-informed choices about best routes, times, or modes to use for their trips. For example, an Internet survey in Pittsburgh and Philadelphia found that 68 percent of users in Pittsburgh and 86 percent of users in Philadelphia had selected alternative travel routes in response to real-time travel information provided on the Web. Additionally, 47 percent of users in Pittsburgh and 66 percent of users in Philadelphia changed their original travel times based on reported traffic conditions (Fekpe and Collins, 2003).

Safety

Rating: Neutral (uncertain). Traveler information can increase traffic safety by warning travelers about incidents ahead, sudden changes in travel speeds, upcoming merges, weather conditions, or road hazards, but only to the extent that drivers respond to such warnings appropriately. On the other hand, VMSs or traveler information provided via cell phones can also distract drivers and therefore introduce new safety risks. For instance, one survey of Southern California drivers found

that 28 percent of drivers considered VMSs to be a distraction (Parentela and Eskander, 2001). To reduce the level of driver distraction, USDOT recommends that motorists be able to read roadside messages in about eight seconds or less; this corresponds to messages of about eight words when traveling at 55 mph, seven words at 65 mph, or six words at 70 mph (USDOT ITS, 2004).

Because there is little evidence about safety improvements due to warnings and advisories and mixed findings about driver distraction, safety effects are rated here as *neutral*, though we describe this rating as being *uncertain*.

Economic Efficiency

Rating: Good. To the extent that traveler-information systems help reduce congestion, they will enable more-efficient use of existing road capacity. In cases in which an ITS backbone has already been developed for other uses, such as ramp metering, traffic-signal control, or incident response, the application of this underlying infrastructure for traffic-related traveler-information systems will provide additional returns on the technology investment.

Environment

Rating: Neutral (uncertain). If traveler-information systems lead drivers to travel during less congested periods of the day, use less congested routes, or forgo trips altogether, the strategy should produce positive environmental effects in terms of reduced emissions from idling and stop-and-go traffic. However, displacing travel to off-peak times and onto other corridors may also lead to an overall increase in VMT or person trips. Lacking empirical evidence to suggest which of these two outcomes is more likely, we have rated traveler-information systems as *neutral* with respect to environmental concerns, though we also characterize this rating as *uncertain*.

Equity

Rating: Neutral. The benefits of traveler-information systems are not concentrated in any specific segment of the population, nor are the

costs unevenly distributed. For this reason, the strategy rates as *neutral* with respect to equity effects.

Studies have shown that such factors as age, sex, and purpose of travel influence the type of information that travelers find most helpful. Some are more interested in descriptive information regarding current conditions, for instance, while others may appreciate advice on suggested alternatives (Muizelaar and van Arem, 2007). Additionally, some segments of the population—such as the elderly or those with low incomes—may not have access to the Internet or cell phones (Zhang and Levinson, 2006). These findings indicate that the type of information presented, as well as the media through which it is presented, will have an effect on which groups find the systems most helpful. As already discussed, however, evidence suggests that the provision of real-time traffic information may lead to the greatest overall congestion-reduction benefits if only some, rather than all, drivers receive that information and act on it. As such, it is possible that even those lacking access to traveler information may still benefit from the fact that others are receiving the information and altering their travel plans accordingly.

Stakeholder Concerns

Rating: Low. This strategy does not impose direct costs on any particular group of stakeholders and thus receives a rating of *low* for this criterion.

General Political Obstacles

Rating: Low. The general public and elected representatives are not likely to oppose the development of traveler-information systems, as this is an additional resource for motorists.

Institutional Obstacles

Rating: Medium/difficult to address—>medium. Traveler-information systems generally require high levels of institutional collaboration, involving efforts of both the public and private sectors and multiple agencies spanning technical, operational, modal, and policy arenas. Institutional cooperation may also be required when the agen-

cies that collect and maintain data are different from those that provide the data to end users. Institutional obstacles have been especially challenging with 511-system deployments. For example, the 511 implementation in the San Francisco Bay Area in the mid-1990s required the Metropolitan Transportation Commission, Caltrans, and other transportation agencies to work with a regional telecommunication company to develop a regionally accessible system. The subsequent designation of 511 as the national traveler-information number helped facilitate the Bay Area's efforts, and, as more regions move forward with 511, implementation schedules are expected to shorten (USDOT ITS, 2001). Even so, the technical cooperation required among different agencies makes it likely that the development of traveler-information systems will remain challenging.

Current Status in the L.A. Region

Rating: Significant. Efforts are under way to expand traveler-information systems in L.A. County. The RIITS effort, managed by Metro, consolidates the various multimodal, multijurisdictional, and multiagency ITSs in L.A. County. Metro acts as an information warehouse, providing data to support a variety of regional applications and clients, including the regional 511 system, the MyTrip real-time trip planner, and customized traveler-information applications offered by Internet-service providers (ISPs).

The regional 511 system, currently under development, will provide a variety of traveler-information services to the general public and span the counties of Los Angeles, Orange, Riverside, San Bernardino, and Ventura. The current plan is to introduce system functionality in several distinct phases (Coleman, 2007). The baseline services, which were expected to be operational in 2008, include information on real-time freeway-traffic conditions (including incidents, speeds, travel times, and congestion), freeway closures, general transit information and automated transit trip planning, real-time status for Metro and Metrolink transit vehicles, specialized transportation services, ride-sharing options, bicycle services, park-and-ride options, and Amtrak trains. This information will be available by telephone and through Metro's existing online trip planner.

The next phase of 511 enhancements will include weather, airport, general emergency, taxi/shuttle, special-event, tourist, and AMBER Alert™ information, again provided through both phone and Internet access. The final stage will attempt to provide services, such as real-time arterial, pedestrian, commercial vehicle operation, and alternative routing information.

Metro's trip-planning feature, which is currently being enhanced, will provide individualized trip information that can be accessed on a repeated basis. When one uses this functionality, either by phone or by Internet, the system will identify the patron and then automatically provide information about the trips that the individual takes on a routine basis. (For example, the system might indicate whether the bus that the user normally rides is running on time for the day in question.) Metro has estimated that about 20 percent of its traveler-information system users routinely request information on the same trips, so this functionality should prove quite helpful. Metro has also recently enabled complete traveler-information Web-site content to be accessed by smaller handheld devices or mobile phones (Anderson, 2007).

ISPs also present interesting partnering opportunities for traveler-information services in the region. LACDPW, for example, currently contracts with Iteris to provide Web-based information on average travel times and speed on freeway segments. ISP-based applications in Los Angeles also provide personalized, subscription (fee-based) services (White, 2007). Metro may also consider providing data to Google Transit and to other ISPs, but, to date, various legal barriers (e.g., restrictive contracts) have prevented this from occurring.

Interaction with Other Strategies

Traveler-information systems share a common information and communication infrastructure with several other applications, such as automated incident detection and response (see Appendix B10), ramp metering (see Appendix B1), signal timing and control (see Appendix B2), and signal prioritization for BRT (see Appendix B25). Implementing these programs together can therefore provide the greatest returns on the necessary infrastructure investment.

Traveler-information systems can also be implemented in conjunction with road pricing strategies, such as HOT lanes (see Appendix B18). For example, the Illinois State Toll Highway Authority collects time-stamped data from toll transponders to estimate travel times between toll plazas. This information is then relayed to motorists traveling along both toll and nontoll roads (FHWA, 2005).

Mandatory Transportation Demand Management Programs

The term *transportation demand management* is used to describe various strategies for reducing automotive travel during peak periods and encouraging better use of other transportation infrastructure. Often implemented through voluntary or incentive-based programs, TDM measures focus on bolstering alternative transportation modes, such as walking (see Appendix B27), biking (see Appendix B28), transit (see Appendixes B24, B25, and B26), ride-sharing (see Appendix B11), telecommuting (see Appendix B12), and flexible work hours (see Appendix B13). TDM programs are commonly implemented by employers—in part because employee commutes constitute a sizable share of peak-hour traffic and in part because employers are in a good position to implement certain TDM options, such as flexible work hours, telecommuting, deep-discount transit-fare programs, and employee vanpools or ride-sharing. They may also be implemented by building developers or managers, who control the parking supply and may also be in a better position to organize ride-sharing efforts among the employees of multiple tenants in a commercial building.

This appendix explores mandatory TDM programs required of either employers or building owners. When applied to the former, mandatory programs would require employers to incorporate a package of TDM strategies in their transportation and benefit policies in order to reduce the number of employees who drive to work alone. Depending on the composition of their workforce and their geographic location, employers may focus on different TDM strategies (for example, telecommuting might be suitable for one work site, while paid-transit

benefits could be more effective at another). Regardless of the strategies incorporated, employers would be required to achieve certain reductions in SOV use. Performance could be measured either as a function of commuter mode split or average vehicle ridership (e.g., 70 cars per 100 employees, for an average ridership of 1.43 employees per car), and compliance could be judged based on achieving a certain percentage reduction in single-occupant commuting or by meeting a specific target (e.g., an average vehicle ridership measure of 1.5). Such programs could also be applied to entire buildings (with multiple employer tenants), in which case they would be implemented by building owners or managers rather than by individual employers. With mandatory programs, employers or building operators who do not meet their goals could be subject to enforcement action, such as fines.

Los Angeles is one of several regions in the United States that already has a program of this type in place; AQMD operates the program, which covers four counties. Note, however, that the primary goal of AQMD's program is to improve air quality rather than to reduce congestion, and employers in the region can opt to pay for other air quality-improvement programs instead of developing a TDM plan if they so choose. The state of Washington also operates the Commute Trip Reduction (CTR) program, which currently applies primarily to the Seattle region, while Oregon has a plan that covers only Portland. In Arizona, Pima County (where Tucson is located) and Maricopa County (where Phoenix is located) have similar programs. In Massachusetts, Cambridge has a program aimed at developers rather than employers. Other existing programs generally cover only very small areas (for example, the CBD of Silver Spring, Maryland). While most major metropolitan regions have outreach programs to work with employers to implement TDM measures at work sites, the majority of these programs are voluntary rather than mandatory.

Washington enacted its CTR ordinance in 1991 as part of its Clean Air Act compliance. The regulations apply only to counties with more than 150,000 residents (nine counties as of October 2007). Every employer with more than 100 employees arriving between 6:00 a.m. and 9:00 a.m. must make a good-faith effort to reduce drive-alone commute trips. Employers must also survey employees every two years

to measure travel behavior. The goal for employers is to reduce solo-driver commutes by 15 percent in the first two years and by 35 percent within 12 years. A state task force reviews the program every two years to recommend to the state legislature whether it should be continued and whether any changes should be made.

The Oregon Department of Environmental Quality operates that state's Employee Commute Options program. Employers with more than 100 employees (the number was raised from 50 employees in February 2007) must provide incentives to employees to reach a goal of reducing drive-alone trips by 10 percent. There is no penalty to employers who fail to achieve this goal as long as they are putting the right incentives in place and meeting other administrative requirements.

In Arizona, the Pima Association of Governments' Travel Reduction Program is similar; employers with more than 100 employees are covered, and there is no penalty as long as the employer is making a good-faith effort. In Maricopa County, the threshold for the number of employees is 50, and its Trip Reduction Program has been in place since 1988.

Cambridge, Massachusetts, has had a Parking and Transportation Demand Management ordinance since 1998. The ordinance covers all buildings with commercial parking. Developers must submit a plan demonstrating that the building will achieve an automotive-commuting mode share of at least 10 percent below the average for the surrounding census tract. Buildings with more than 20 commercial parking spaces must conduct an annual review, reserve 10 percent of their parking spaces for ride-sharing, and provide an equivalent of 10 percent of parking for bicycles. If the building fails to meet the target, the developer can be fined, or, in a worst-case scenario, the city can shut down the parking facility.

Evaluation of Strategy

Cost/Revenue Implications

Rating: Low cost. From the public's perspective, creating and implementing a mandatory employer TDM program would entail

ongoing operating costs, including staff to monitor and enforce the program. If fines for failing to meet trip-reduction goals were set sufficiently high, a region could receive net revenue from the program, though this would represent neither a steady nor a popular revenue stream. Washington State currently spends about \$5.5 million every two years to assist local jurisdictions and monitor the program. As another data point, AQMD spends \$800,000 annually to monitor its program, and it collected \$1.2 million from January to July 2007 from employers choosing to opt out of the trip-reduction component and participate in the Air Quality Investment Program instead (Gomez and Thomas, 2007).

Short-Term Effectiveness in Reducing Congestion

Rating: Medium. Mandatory TDM programs could result in at least a moderate reduction in automotive commute trips and VMT, since such programs typically apply to enough commercial buildings or large firms to encompass a sizable portion of the overall working population. Because most commute trips occur during the morning and evening rush hours, this could result in appreciable congestion relief in the short term.

Studies of prior mandatory TDM programs in the L.A. region offer some evidence of this strategy's potential effectiveness. For example, the Coastal Transportation Corridor ordinance (discussed in greater detail later) required developers in several parts of the city to implement strategies intended to reduce single-occupant commuting, as well as to pay considerable fees for each new evening peak-hour trip generated beyond the specified limit. Blankson and Wachs's (1990) examination of the program determined that the carpool rate for buildings covered by the ordinance was more than twice that for similar buildings in areas not covered by the ordinance. That said, the carpool share was still rather small (7.4 percent for buildings covered by the ordinance versus 3.5 percent for other buildings), while the proportion of employees who drove alone remained comparable (86.8 percent versus 87.9 percent).

Another study, by Giuliano, Hwang, and Wachs (1993), examined the effects of AQMD's Regulation XV (also discussed in more detail

later), which appeared to be more successful than the Coastal Transportation Corridor ordinance. The authors found that, after employers in Los Angeles had participated in the program for a year, the AVR (calculated as the number of employees arriving at work between 6:00 a.m. and 10:00 a.m. divided by the number of vehicles arriving at the work site) increased from 1.213 to 1.246 (this translates to a decrease of two cars for every 100 employees).¹ Of the 1,110 employment sites reported in AQMD's database, AVR increased at 69 percent of the sites but fell at 31 percent. Those sites where AVR increased tended to have lower starting AVRs to begin with; they also tended to offer more employee incentives, which appeared to be more effective than disincentives. The greatest change in mode share came from increases in carpooling (as distinct from vanpooling). For a smaller number of employers that had been participating for two years when the evaluation was conducted, the AVR continued to increase, from 1.258 after the first year to 1.304 in the second (an additional reduction of about three cars per 100 employees), and the share of drive-alone commuting also continued to decline (from 69.7 percent in the first year to 65.4 percent in the second).

Long-Term Effectiveness in Reducing Congestion

Rating: Low. Focusing just on commuter trips, mandatory building- or employer-based TDM programs should continue to be effective in the long term, since ongoing participation would be required. (It should be noted, of course, that effectiveness also depends on the consistency and strictness of enforcement, as employers or building managers will be less likely to comply if they feel that infractions will not be punished.) For example, the State of Washington reviews its overall progress every two years. The 2005 report found that the CTR had reduced vehicle trips by 20,000 per day, that the percentage of drive-alone commuters at CTR work sites had declined from 70.8 per-

¹ The total number of employees showing up at work plus the total number of cars they collectively drive, divided by AVR, is 1.245. The inverse of employees per car is cars per employee ($1/1.213 = 0.824$, $1/1.245 = 0.803$). Subtracting 80.3 from 82.4 results in a decrease of two cars per 100 employees.

cent in 1993 to 65.7 percent in 2005, and that delays during the morning peak hours had been reduced by 11.6 percent. The number of trips reduced per day reached a plateau in 2001, however, suggesting that, while the CTR program has been effective, decreases in auto trips will not continue indefinitely. While some employers have met the stated percentage goals, more than two-thirds have not (WSCTR, 2005).

A study of the Lloyd District in Portland found that, from 1997 to 2005, the percentage of employees driving alone decreased from 60 percent to 43 percent. Most of the mode shift went to transit; carpooling actually decreased during this period (Lloyd Transportation Management Association, 2006). In Tucson, regular program evaluations are conducted to measure the percentage of employees who drive alone and those who use alternative modes at least one day per week. In 2005, 78.7 percent drove alone; previous-year percentages were not reported. The percentage of commuters who commuted by non-SOV modes at least one day per week rose from 17.6 percent in 1989 (the first year the program was in effect) to 30.4 percent in 2005; however, this figure has been relatively steady since 1994, again seeming to indicate that such programs have a natural leveling-off point (Pima Association of Governments, 2006). Cambridge has also seen a slight decline in the percentage of employees who drive alone to work, from 51.2 percent in 1990 to 50.6 percent in 2000 (Nelson\Nygaard Consulting Associates, 2006).

Despite reductions in automotive commuting, effective TDM programs will not necessarily lead to long-term reductions in congestion, especially in the afternoon peak travel period. This is because commuting represents a much smaller percentage of travel than most people would expect—approximately 15 percent of all trips and 18 percent of all miles traveled (Pisarski, 2006). While the percentage of commuting vehicles is no doubt considerably higher during rush-hour periods, the share of noncommuting traffic is still surprisingly large, especially during the afternoon peak, when many drivers are engaged in activities, such as taking children to and from after-school programs, shopping, or visiting friends. Because mandatory TDM programs apply just to employees, and because employees constitute just one portion of the drivers on the road during peak periods, any short-term conges-

tion relief resulting from mandatory TDM programs will be subject to erosion over the longer term based on the effects of triple convergence. That is, as commuters—based on incentives offered by their employers or building managers—switch to other modes, noncommuters will soon notice that the roads are flowing more freely than they did in the past. Noncommuters will then converge on the newly freed capacity from other times, other routes, and other modes of travel, slowly but surely offsetting at least some of the gains achieved through the mandatory TDM programs. For this reason, mandatory TDM programs are rated as *low* in terms of long-term reductions in delays. They may help slow the growth of travel, but they are unlikely to lead to long-term declines in aggregate peak-period road use.

Mobility, Accessibility, and Traveler Choice

Rating: Neutral. Several of the TDM measures commonly implemented by employers—such as flexible work hours, telecommuting, subsidized transit passes, and subsidized vanpools—increase the travel choices available to commuters; specifically, they allow employees to travel during off-peak hours, work from home rather than commuting on occasion, or save money by using transit or ride-sharing. On the other hand, some employers, in their effort to meet trip-reduction goals, might choose to implement certain disincentives—such as the elimination of free parking—that could be viewed as coercing employees to switch modes. Though perhaps effective in stimulating mode shift, disincentives would be viewed negatively in terms of traveler choice. Taking together the positives and potential negatives, mandatory TDM programs are rated as *neutral* in terms of their effects in this category.

Safety

Rating: Neutral. If mandatory TDM programs include telecommuting as an option and thus reduce the total number of trips, there could be some safety-related benefits. On the other hand, if a program leads to significant pedestrian and bicycle mode share increases, there could be negative safety-related consequences. Overall, however, net safety effects are likely to be negligible.

Economic Efficiency

Rating: Neutral (uncertain). TDM programs are often ranked as performing well on this criterion because they encourage better use of existing transportation infrastructure, such as transit and limited parking. Whether they can accurately be described as efficient, however, depends at least in part on how much it costs to reduce vehicle trips. Studies that have examined different work sites show a wide range of estimates. In one review, for instance, the cost to reduce a single vehicle trip ranged from \$0.21 to more than \$3.50 (ICF Consulting, 2004). The existing level of infrastructure for other modes of commuting will strongly influence the effectiveness of reducing vehicle trips through TDM measures; if there is limited transit access throughout a region, few opportunities to walk or bicycle, and indifferent employer support, it is likely that the per-trip reduction costs will be fairly high. Taking these factors into consideration, we rate mandatory TDM measures as *neutral* with respect to economic efficiency, though we describe this rating as *uncertain*; further studies of the specific contextual factors that would influence the cost-effectiveness of mandatory TDM programs in various regions of Los Angeles would be needed to resolve this uncertainty.

Environment

Rating: Good. Reducing single-occupant commuting has a beneficial environmental impact, resulting in lower emissions per commuter.

Equity

Rating: Good. Lower-income employees generally spend a greater share of their income on transportation than do higher-income workers; as such, additional employer incentives to use other modes offer the potential of improving their economic situation. For example, employers might provide paid transit benefits, which would lower the out-of-pocket cost for employees who ride transit.

Stakeholder Concerns

Rating: High/can partially address—>medium. Depending on the specific implementation, either employers or building owners must shoulder the cost of operating mandatory TDM programs, and they are likely to view such requirements as an unnecessary burden or an unfunded mandate. As discussed in greater detail later, pressure from the business sector led to the eventual repeal of AQMD Regulation XV and the subsequent passage of California state legislation forbidding mandatory trip-reduction programs. By most accounts, this would constitute a high level of stakeholder resistance. That said, in certain cases, businesses have proven to be more accepting of such regulations (Nelson\Nygaard Consulting Associates, 2006). In Washington State, for example, the CTR task force includes business representatives, and the corporate sector as a whole has been broadly supportive of the ordinance (Kadesh and Roach, 1997). Given the private costs involved, however, the Washington experience is likely to be more the exception than the rule.

The size of the employer may influence reactions to mandatory TDM programs. Larger employers in L.A. County are already subject to AQMD Rule 2202, which covers work sites of more than 250 people. These larger employers may therefore support legislation that extends the mandatory provision to smaller employers, on the grounds that it would level the playing field. Smaller employers that were previously not subject to such regulations may object to the costs involved, arguing that they are less able to absorb them than larger employers are. If the mandatory programs were applied to building owners or managers, they would also likely complain that the regulations are burdensome and expensive, forcing them to increase the rent that they charge their tenants.

Business groups may be more sympathetic to such regulations if they are widely and fairly applied, if they have some input into their final form, and if the public sector makes the transition easier through incentives, recognition programs, or other means. The Washington State program provides a good example of how the public sector brought business leaders on board; employers have provided feedback through focus groups, and local governments must allow employers to custom-

ize their plans (Kadesh and Roach, 1997). Business groups might also be involved in local transportation decisionmaking processes—for example, meeting with transit officials to discuss ways to better serve their work sites.

General Political Obstacles

Rating: Low. Other than the stakeholder concerns among business groups just discussed, mandatory TDM programs are unlikely to stir much political opposition and, in fact, may prove quite popular. First, many employees would directly benefit from the programs—for example, through the provision of subsidized transit passes. Second, the programs would help relieve congestion to some degree (though likely more in the short term than the long term, as just argued), and the population as a whole would also view this favorably. The political influence of business stakeholders, however, should not be underestimated, as several areas have weakened their mandatory programs over time, presumably as a result of such pressure. For example, the Oregon program, which previously covered all employers with more than 50 employees, recently increased the minimum threshold to firms with 100 or more employees.

Institutional Obstacles

Rating: High/difficult to address—>high. As discussed later, California's Senate Bill (SB) 836 forbids AQMD from implementing mandatory trip-reduction ordinances. (Note that AQMD Rule 2202 does not violate this prohibition because it allows employers several options other than trip reduction to comply with its provisions; Santa Monica's ordinance 1604 follows a similar strategy.) A companion bill, SB 437, forbids any jurisdiction in the state from adopting a mandatory trip-reduction ordinance for employers unless required by federal law.² The way the law is worded, this rule does not appear to allow any exceptions. It would likely require a legal opinion to determine whether the law also applies to building managers, although, to the extent that a building manager would require cooperation from employers, this

² See California Codes, Health and Safety Code, sections 40454 and 40719.

would seem to be prohibited also. It thus appears that the implementation of mandatory trip-reduction programs would require additional legislation at the state level to override the previous ordinances.

Current Status in the L.A. Region

Rating: Moderate. The L.A. area has had various mandatory TDM programs applied to both developers and employers for more than 20 years. In the mid-1980s, there was a spurt of new commercial development and an increasing level of concern about the traffic it would produce. The Coastal Transportation Corridor Specific Plan, passed by the L.A. City Council in September 1985, covered new non-residential developments in Venice, Westchester, and around LAX. Any development that would generate more than 100 trips during the evening peak hours had to institute measures to reduce trips by 15 percent (from predicted traffic) as well as pay a fee of \$2,010 per new evening peak-hour trip beyond the specified limit (Blankman and Wachs, 1990). However, despite predictions that the plan would raise \$9 million annually, by 1991, it had raised only \$5.3 million, in part because of development delays and in part because of provisions that allowed the fees to be paid over a 20-year period (Rainey, 1991). It was repealed in 1993, presumably due to pressure from the commercial development community.

In early 1987, the L.A. City Council approved a Traffic Reduction Improvement Plan. Unlike the Coastal Transportation Corridor Specific Plan, this provision applied to all commercial development, not just new construction. At the time of adoption, specific implementation areas had not yet been identified (Roderick, 1987). Later that same year, the city council also approved a measure requiring employment sites of 700 employees or more to institute ride-sharing or shift their work hours (Boyarsky, 1987).

In October 1987, AQMD passed Regulation XV, which applied to all work sites with more than 100 employees and required progress toward a particular AVR target (generally 1.75 for downtown Los Angeles, 1.5 for areas of moderate density, and 1.3 for the least dense areas). Employers had to develop Transportation Improvement Mitigation Plans to comply with the requirements. Employers also had to

appoint an employee-transportation coordinator who would be responsible for managing the plan and ensuring compliance. In the wake of its passage, Los Angeles dropped its other mandatory TDM requirements, since smaller employers were covered under Regulation XV. However, a key difference was that the L.A. ordinance had covered work sites and not employers; if the 700 or more employees at one work site worked for different employers, ride-sharing had to be implemented by building managers, unlike with Regulation XV (Snyder, 2007).

In response to criticism from the business community about the cost of complying with Regulation XV, the state legislature passed SB 836, which banned mandatory trip-reduction programs. In response, AQMD adopted Rule 2202 in December 1995. This made two primary changes: (1) the threshold for compliance increased from 100 employees to 250 and (2) employers could now choose one of three ways to comply with the regulation: meet or work toward meeting a target AVR, pay a set fee per employee into an air-quality fund, or purchase air-quality credits.

Rule 2202 remains in effect, covering all of Orange County and the nondesert portions of Los Angeles, Riverside, and San Bernardino counties. An employer is required to participate if it has 250 or more employees who arrive at work between 6:00 a.m. and 10:00 a.m. As of July 2007, Rule 2202 covered approximately 1.1 million employees at almost 1,500 work sites. According to AQMD staff, approximately half of all covered employers choose paid options, while half try to increase their AVR (Gomez and Thomas, 2007). Rule 2202 covers only employers, not developers or building owners.

If employers choose to participate in the Employee Commute Reduction Program under Rule 2202, they must institute at least five marketing strategies, five basic strategies (such as support for ride-sharing or flextime scheduling), and five direct strategies (such as employer-paid transit or vanpool benefits). While employers are not penalized as long as they are making a good-faith effort, if their plan does not result in meeting the target AVR, they must adopt additional measures (Gomez and Thomas, 2007).

Interaction with Other Strategies

Strategies that make it easier to use alternative commute modes would complement mandatory TDM programs. This could include everything from HOV lanes (see Appendix B3) and more frequent transit service (see Appendixes B25 and B26) to better infrastructure for walking (see Appendix B27) and bicycling (see Appendix B28). As noted, it is difficult to achieve large gains from programs to reduce drive-alone commuting unless employees have attractive alternatives.

Driving Restrictions

Most driving restrictions implemented to date have been intended to reduce air pollution, though they can help reduce congestion as well. Such restrictions can be implemented in a number of ways: by time (e.g., weekend driving bans), by place (e.g., a ban on driving in a city center), by vehicle characteristics (e.g., commercial vehicles or vehicles with odd- or even-numbered license plates), or some combination of the three. To be effective, driving bans must be accompanied by strict enforcement.

Driving restrictions are most commonly used in South America. The oldest program is in Mexico City, where the *Hoy No Circula* (HNC, or One Day Without a Car) program was introduced in 1989. Restrictions are in effect from 5:00 a.m. to 10:00 p.m. on weekdays. The effective impact on drivers is that, one day per week, certain vehicles cannot legally be used (for example, license plates ending in 5 or 6 cannot be driven on Mondays).

Other cities restrict use during peak periods only. In Bogotá, the *Pico y Placa* (Peak and License Plate) program restricts drivers from driving during weekday peak hours, defined as 6:00 a.m. to 9:00 a.m. and 4:00 p.m. to 7:00 p.m. Restrictions are based on the license-plate number, with each vehicle banned from driving during the peak hours twice a week. *Pico y Placa* began in 1998; when introduced, the restricted driving hours were shorter (two hours each morning and evening). Also, the days on which drivers are restricted from driving rotate annually. São Paulo restricts each vehicle once per week from 7:00 a.m. to 8:00 a.m. and 5:00 p.m. to 8:00 p.m. Santiago restricts drivers one

day per week under its *Restricción Vehicular* (Vehicle Restriction) program, but vehicles with catalytic converters are exempted, and the restrictions apply only to certain arterials (Cracknell, 2000).

Athens, the only European city with license-plate driving restrictions, limits private vehicles in the city center, based on an alternating license-plate scheme (for example, odd-numbered plates can travel only on odd-numbered days) (ILS, 2000). The ban began in the late 1970s for weekends only but was extended in 1982 to weekdays and remains in effect (de Quetteville, 2003).

More-limited bans have been used for special events, for occasional car-free days, for emergencies, and for environmental reasons. Seoul used driving restrictions when it hosted the FIFA World Cup™ soccer tournament in 2002; Beijing employed similar restrictions before and during the Olympics in 2008 in an effort to reduce air pollution. A number of cities observe a car-free day annually in September, generally closing off downtown areas to vehicles, and some cities have pedestrian-only streets or districts.

Evaluation of Strategy

Cost/Revenue Implications

Rating: Low cost. Driving restrictions may require modest capital costs, such as the creation of checkpoints. The main operating cost is enforcement. While cited as fairly inexpensive or easy to enforce (Davis, 2008; Cracknell, 2000), more specific cost figures and implementation details (number and type of checkpoints) are not readily available.

Short-Term Effectiveness in Reducing Congestion

Rating: Medium. Experience from other cities suggests that driving restrictions based on license-plate numbers can be moderately effective in the very short term (days or weeks), as reactions to oil-price hikes or environmental problems, or for demonstration projects, such as car-free days. Over longer periods (months to a few years), however, drivers can find ways to legally circumvent the restrictions. Wealthier indi-

viduals, for example, may purchase additional vehicles such that one is always legally available to drive, or they may use taxis or limousines to a greater degree. This obviously undermines the rationale for introducing the system in the first place, while the burden of compliance falls more heavily on people with more-limited economic means.

Households in the five-county region of Southern California have an average of 2.5 vehicles (SCAG, 2007b), meaning that a high proportion of households already have enough vehicles at their disposal to drive daily regardless of restrictions. Moreover, many households in the region have sufficient disposable wealth to purchase more vehicles if needed to circumvent the restrictions.

It should also be noted that, if driving restrictions are not applied uniformly throughout the entire region, traffic will likely worsen in areas not covered by the restrictions. For example, a study of the Athens, Greece, program after one year found that “although traffic was clearly relieved within the cordoned area, traffic conditions in the areas immediately adjacent to the [restricted area] worsened substantially” (Matsoukis, 1985, p. 125). Scaling the driving restrictions to cover an entire metropolitan area is, of course, possible, but doing so will likely increase political resistance to the strategy and make it more difficult to provide sufficient alternative transportation options. Given these factors, we assess the short-term effectiveness of driving restrictions as *medium* rather than high.

Despite such longer-term limitations, one observer suggests that driving restrictions can be effective in buying time while more-permanent solutions are developed: “Provided [that] the period when schemes are effective can be used to develop more comprehensive and sustainable measures, the measures may be worthwhile, particularly when they are aimed at emergencies such as air pollution alleviation” (Cracknell, 2000, p. x).

Long-Term Effectiveness in Reducing Congestion

Rating: Low. The effectiveness of driving restrictions based on license-plate numbers will typically decline significantly over the longer term as households acquire more vehicles to circumvent the restrictions. To begin with, having an additional vehicle allows household

members to drive even on days when the restrictions apply to one of their vehicles. Second, the purchase of additional vehicles may increase total household driving on days when the restrictions do not apply. Consider, for example, a two-driver household that shares a single automobile. At any particular time, only one of the drivers can be using that car. If the household purchases a second car in response to driving restrictions, it then becomes possible for the two drivers to use both of the cars on days when the driving restrictions do not apply to either vehicle. The phenomenon of additional vehicle ownership leading to additional household driving has been well documented; see, for example, the discussion in Downs (2004).

Because drivers can skirt the spirit of driving restrictions—either by purchasing more vehicles or by taking more trips by taxi—most programs developed to date have proven ineffective in providing either long-term air-quality improvements or congestion relief. As noted in an International Energy Agency report, “In the extreme case of Mexico City and Athens, long-term implementation of the policy has been completely ineffective” (IEA, 2005, p. 64). In Mexico City, there is ample evidence that auto ownership and total driving increased following introduction of the driving restrictions (Eskeland and Feyzioglu, 1997). For example, between 1983 and 1989, before the HNC program was instituted, the number of registered vehicles in Mexico City increased by about 7,000 per year. Between 1990 and 1993, after HNC was in place, the annual growth in vehicle registration mushroomed to 239,000 per year. To make matters worse, many of the vehicles added to the fleet were older, more polluting cars; once the HNC was implemented, Mexico City rapidly evolved from a net exporter of used vehicles (about 74,000 per year prior to the HNC) to a net importer of used vehicles (about 85,000 per year after the HNC was in place). Finally, economic-modeling results suggest that the total growth in fuel consumption following introduction of the HNC far exceeded the growth that would have occurred absent the program. The policy’s ineffectiveness does not seem to stem from lack of enforcement; according to one report, “Compliance is generally believed to be high: the police are visible and fines are heavy” (Eskeland and Feyzioglu, 1997, p. 383).

Results in Athens have been similarly disappointing. After the restrictions were introduced in Athens, according to one source,

The number of households with two vehicles increased, and motorists who were not allowed to enter the city drove around the city to get to their destination, thereby increasing the length of their trips while also increasing emissions. In addition, the cars bought for use on off-days are often cheap, second-hand vehicles, which tend to be more polluting. (WRI, 1996, p. 93)

Another observer noted, “Despite the odd-even scheme, the number of cars in the center has actually increased dramatically” (Vlastos, 2002, p. 1). While congestion did decrease in the short term, the city has also put into place longer-term measures, such as a new heavy rail system and a ring road to help alleviate center-city congestion.

The Bogotá model seems to have been more successful; for example, travel speeds have increased by 43 percent with the driving restrictions (Winchester, 2005). It is thought that second car purchases have not been as great a problem, since the driving restrictions are only in peak hours. However, the policy was implemented alongside a major new BRT system with miles of dedicated busways, and many residents cannot afford second cars (Dodder et al., 2004). Neither of these conditions applies in Los Angeles, where the majority of buses must share congested right-of-way with automobiles and where average income levels are much higher than in Mexico City.

It is certainly conceivable that Los Angeles could develop an alternative approach to driving restrictions, one that would be more difficult to circumvent by purchasing additional cars. For instance, each household might be issued a set of placards or electronic transponders for their vehicles that indicate the days on which the vehicles cannot be driven, and these could be set up so that members of a household are not allowed to drive *any* of their vehicles on a given day. Even this approach would likely prove problematic, though. To begin with, creative drivers might still find ways to skirt the rules; for example, households might swap placards with one another, or they might even swap vehicles as needed. In addition, to the extent that effective enforcement strategies can be developed, political resistance to the program will

inevitably increase. In other words, the more successfully the program prevents households from driving on certain days, the greater the political resistance will be.

Finally, the phenomenon of triple convergence also limits the longer-term congestion-reduction effects of driving restrictions. On any given day, one part of the population will be restricted from driving, while the remainder will be allowed to drive. Among the latter group, there will likely be some individuals who previously avoided driving during peak hours to avoid congestion. Yet if the driving restrictions lead to noticeable reductions in congestion, these same individuals may choose to drive during peak hours once again. Over time, this will slowly erode any initial congestion-reduction benefits that result from driving restrictions.

Mobility, Accessibility, and Traveler Choice

Rating: Bad. Driving restrictions reduce mobility, since they remove the ability to drive every day without adding alternative travel incentives or infrastructure. To the extent that driving restrictions reduce congestion, they may enhance the speed and attractiveness of existing bus service. On balance, however, the overall effects on mobility, accessibility, and traveler choice are expected to be negative.

Safety

Rating: Good. To the extent that driving restrictions reduce overall vehicle travel, they should reduce the accident rate as well. In Bogotá, for instance, traffic accidents decreased by 28 percent with the driving-restriction program (Reymond, 2003). Comparable information for other cities was not available.

Economic Efficiency

Rating: Very bad/difficult to mitigate—>very bad. Economic efficiency is rated as *very bad*, since driving restrictions function as a market distortion, restricting trips without regard to their value to the drivers and offering no mechanism to allow those who value such trips more highly to make them. In addition, as suggested by the evidence from Mexico City and Athens, they encourage households to purchase

more vehicles than they would otherwise need, representing an inefficient use of household resources. Unfortunately, the nature of driving restrictions does not offer many possibilities for mitigation. Allowing exceptions would obviously weaken the original intent, although, in the studies reviewed, there was little evidence that widespread exemptions have been requested or granted. Also, unlike other aggressive traffic-reduction strategies, such as cordon congestion tolls, driving restrictions do not produce revenue that could be used to help improve other transportation services that drivers could use instead.

Environment

Rating: Neutral. According to one study, Mexico City's HNC program has been ineffective in improving air quality, which was the purpose of the program. Air quality as monitored throughout Mexico City has not improved since the introduction of HNC, and it appears to have worsened on weekends (when restrictions are not in place). While the program was intended to shift some automobile trips to transit, subway and bus ridership has not increased. Instead, it seems that many drivers have either switched to taxis or purchased second vehicles (Davis, 2006). If second vehicles or taxis are more polluting than the vehicles they replace, air quality will worsen.

In Bogotá, emission reductions from driving restrictions are estimated at 10 percent (Winchester, 2005). Anecdotally, Athens has less pollution now than when the restrictions were introduced, but most observers seem to credit the new subway rather than the restrictions.

While air quality as a motivation for driving restrictions may not be as important in Los Angeles as in these cities, given California's strict emission controls for vehicles, it still seems likely that the policy could have the unintended consequence of residents holding on to higher-emission vehicles longer to ensure that they have access to multiple vehicles. Though the evidence from other cities is mixed, on balance, we suspect that the environmental effects would be *neutral*.

Equity

Rating: Very bad/difficult to mitigate—>very bad. As a strategy implemented on its own, imposing driving restrictions would have

negative equity implications if higher-income households with multiple vehicles were unaffected and lower-income households had to restrict their driving. One qualitative assessment of the Athens system calls it “a tax on the poor, who could not afford a second car” (de Quetteville, 2003, p. 3).

Evidence from the 2000 Census Transportation Planning Package database suggests that there would be similar equity issues in Los Angeles. Table B17.1 provides a breakdown of the number of automobiles owned by households in different income groups in the county as of 1999. Households in the lowest income group—those making less than \$50,000 per year—represent about 57 percent of all households in Los Angeles. Among this group, 48 percent have just a single vehicle, and these households would be most affected by driving restrictions (households with no cars would likely be less affected, though there could be negative outcomes for those who share rides with other lower-income car-owning households). For all other income groups, the share of households with a single vehicle is much lower. In contrast, households with two or more vehicles would still be able to drive on a daily basis under the restrictions. In the lowest income

Table B17.1
1999 Auto Ownership, by Income Group in L.A. County

Household Characteristic	1999 Household-Income Group				All Groups
	< \$50,000	\$50,000– 100,000	\$100,000– 150,000	> \$150,000	
Number of households	1,785,480	877,080	276,975	196,755	3,136,290
Percent of total households	57	28	9	6	100
Percent owning no vehicle	19	4	2	3	12
Percent owning 1 vehicle	48	27	15	13	37
Percent owning 2 vehicles	25	45	48	50	35
Percent owning 3 vehicles	6	17	22	23	11
Percent owning 4+ vehicles	2	7	12	11	5

SOURCE: Compiled by the authors from FHWA (2008).

group, just 33 percent of households have two or more cars. For higher income groups, the share of households with two or more cars is much larger, ranging from about 69 percent for the \$50,000–\$100,000 category up to about 84 percent for the \$150,000+ category.

Unfortunately, driving restrictions do not generate revenue that can be used for other transportation improvements to alleviate these equity concerns. Mitigation would require significant investment in transit and other alternative modes, but who would provide the necessary funding for such investments is unclear.

Stakeholder Concerns

Rating: High/difficult to address—>high. Different stakeholders might raise different objections depending how implementation is proposed. If the restrictions cover a relatively small center-city area, business and neighborhood associations in that area might object, claiming that the restrictions would cause undue hardship on employees and residents. Associations just outside the area, meanwhile, might be concerned about spillover traffic. For a much larger area, trucking groups might raise concerns about access. Given that significant driving restrictions have not to date been implemented in the United States, that they have been unsuccessful—and perhaps even counterproductive—in such cities as Mexico City and Athens, and that many areas in L.A. County lack access to high-quality transit as an alternative to driving, we would anticipate that the stakeholder objections would be strenuous.

Note that substantial investments in transit could alleviate some concerns about access and spot congestion, though current transportation-funding shortfalls at the state and county levels make this unlikely. There would also need to be some flexibility given to trucks to avoid long lines of trucks waiting to enter a restricted area; however, some of these concerns might be alleviated with the use of peak-hour rather than full-day restrictions.

General Political Obstacles

Rating: High/difficult to address—>high. Driving restrictions have generally been used in cities in developing countries. The only

city in a developed country to adopt such a policy is Athens, and it has been in effect for more than 25 years. When first introduced, according to one observer,

The immediate public reaction was one of horror. The authorities had in effect barred half the population of Attica from crossing the Dactylios, or Athens ring road, on any given weekend. Police were stationed on the entrance to the restricted area and issued high fines to those who transgressed. The law was so unpopular that the opposition Socialists (Pasok) promised to scrap it when they came to power. In fact, the scheme was revised and extended under Pasok, and in 1982 the car ban was introduced on weekdays too. (de Quetteville, 2003, p. 3)

The reversal was likely in response to the worsening of air pollution, which was, by the early 1980s, the worst in Europe (Howe, 1983) and was accompanied by other restrictions on industry.

In Bogotá, while the restrictions were at first unwelcome, voters in 2000 approved a stringent ban on all private vehicles during peak hours, to begin in 2015. Only about 20 percent of the population owns vehicles, however, so the majority would not be personally inconvenienced (Montgomery, 2007).

Driving restrictions have not been introduced in the United States except in some limited cases of pedestrian malls and emergencies. It is difficult to imagine that L.A. motorists would receive this policy well, and many drivers would probably just purchase or use second vehicles. Voters with access to only one vehicle would likely complain about the unfairness that others already have multiple vehicles and can effectively avoid any restriction.

Political issues might vary depending on whether restrictions were adopted on an areawide basis, as in Mexico City; in a center city, as in Athens; or along arterials, as in Santiago. If the area were fairly small, restrictions might increase traffic along its perimeter, which happened in Athens. This would mean political battles over where the perimeter would be drawn, although fewer jurisdictions would be affected. If a large area were affected, it would require a high degree of interjurisdictional coordination.

Institutional Obstacles

Rating: Low. Institutional obstacles are not expected to be significant. The main institutional problem to address would be who would enforce the restrictions. A multijurisdictional area would require discussions about whose police force would be responsible for enforcement or whether multiple forces might be involved and how revenues from fines would be divided. Fines would need to be set at a sufficiently high level to discourage noncompliance, and a strategy for identifying drivers disobeying the restrictions would have to be developed.

Current Status in the L.A. Region

Rating: None. As noted in the preceding section, driving restrictions at this scale have not been adopted anywhere in the United States.

Interaction with Other Strategies

Driving restrictions, to be effective, must be implemented in conjunction with strategies that give drivers other options to reach their destinations. This might include transit improvements (see Appendixes B24, B25, and B26), as occurred in Athens and Bogotá; ride-sharing programs (see Appendix B11); telecommuting programs (see Appendix B12); pedestrian improvements (see Appendix B27); and bicycling improvements (see Appendix B28).

High-Occupancy Toll Lanes

HOT lanes provide lone drivers with the option of using free general-purpose lanes or paying a toll to use faster and less congested priced lanes. Travelers who form carpools are typically allowed to access the faster-moving toll lanes either at no charge or at a discount. The HOT-lane concept has been gaining in popularity across the county, in part due to the early success of local implementations on SR 91 in Orange County and on I-15 in San Diego. Apart from travel-time savings, HOT lanes also provide travel-time reliability benefits (Small, Winston, and Yan, 2006), and users perceive greater comfort and safety when using HOT lanes (Sullivan, 2000). HOT lanes can be implemented in any of three ways:

- conversion of HOV lanes to HOT lanes
- conversion of general-purpose lanes to HOT lanes
- addition of new lanes that are operated as HOT lanes.

Of these, the first and second options are the least expensive; the third is the least controversial. Note that converting from HOV lanes to HOT lanes works best when there is excess capacity in the HOV lanes—that is, there is ample spacing between carpool vehicles even in the peak travel hours. If this is not the case, one alternative would be to raise the number of passengers needed to qualify as a carpool (e.g., to raise the cutoff from two passengers to three passengers) so as to create the excess capacity required for HOT-lane conversion. Otherwise, it becomes necessary to either build new lane capacity or convert one or more existing general-purpose lanes to establish HOT lanes.

In the following discussion, we differentiate between these cases where relevant. Other important dimensions of variation in HOT-lane policy that can have a strong effect on their performance include the carpool policy adopted (i.e., HOV 2+ versus HOV 3+), the use of static pricing (in which prices are determined ahead of time based on analysis of historical travel-flow patterns) or dynamic pricing (in which prices are determined in real time based on the current level of traffic), and the objective used to determine toll rates (e.g., revenue maximization versus maintaining a certain level of service in the lane).

Evaluation of Strategy

Cost/Revenue Implications

Rating: Medium revenue. HOT lanes have the potential to generate revenues in excess of amortized capital and operating costs (Poole and Orski, 2000). Since opening in 1998, the San Diego HOT lanes, which were converted from an existing HOV facility, have generated approximately \$7 million in net revenue that has been used to fund express bus service in the corridor (SANDAG, 2007). The 91 Express Lanes generate total revenues in excess of \$29 million per year (Obenberger, 2004); these lanes were constructed as new capacity, however, so a large share of this total must be allocated to repaying the initial capital expense of building the lanes. If Los Angeles were to develop a network of HOT lanes on all major highways through the conversion of existing HOV or general-purpose lanes, it is certainly conceivable that total net revenues could fall in the range of tens of millions of dollars annually.

Revenue generation is increased in those corridors that adopt higher carpool standards (e.g., requiring at least three passengers per carpool instead of two) or provide small discounts as opposed to free access to carpools. The costs of implementing HOT lanes tend to be significantly lower (and, in turn, the net revenues higher) when existing general-purpose or carpool lane capacity is converted to HOT lanes, as opposed to adding entirely new capacity.

Short-Term Effectiveness in Reducing Congestion

Rating: Medium. In discussing the effects of HOT lanes on traffic congestion, it is necessary to distinguish between travel conditions in the HOT lanes and in the free, general-purpose lanes. Demand for driving in the HOT lanes is managed through pricing, and the prices are allowed to vary as needed (i.e., by time of day and day of week, in the case of static pricing, or by the prevailing level of traffic, in the case of dynamic pricing) so as to ensure free-flowing conditions. As a result, HOT lanes should be very effective at preventing congestion in the priced lanes themselves, and this has in fact been the case with all HOT-lane implementations to date. On the SR-91 facility in Orange County, travel speed in the priced lanes during peak hours averages between 60 and 65 mph, while speed in the adjacent free lanes averages just 15 to 20 mph (Obenberger, 2004). There has not been a single case in which HOT lanes have failed to control congestion, provided that prices are allowed to vary with demand.

The effects on congestion in the remaining general-purpose lanes vary to some extent based on the type of HOT-lane implementation. If an existing carpool lane is converted to a HOT lane, some single-occupant drivers from the free lanes will choose to pay the toll in order to travel at higher speed in the HOT lanes. By drawing off a small percentage of the single-occupant drivers, the establishment of a HOT lane can lead to slight reductions in congestion in the general-purpose lanes as well.

Though it may at first seem counterintuitive, converting a formerly free general-purpose lane into a HOT lane may also reduce congestion in the remaining free lanes. The primary reason is that, when congestion becomes severe (with travel speeds dropping below, say, 30 or 35 mph), the per-lane throughput of highways begins to deteriorate rapidly. By establishing a HOT lane in which prices are used to achieve optimal flow conditions, the per-hour vehicle capacity in the HOT lane is effectively increased. Assuming that the total number of cars trying to use the highway remains more or less the same (which would be the case in the short term), the remaining general-purpose lanes would have (slightly) fewer cars to accommodate, so congestion in the free lanes should ease as well.

Finally, when HOT lanes are added as new capacity alongside the existing general-purpose lanes, traffic congestion across all lanes can be significantly improved as traffic is spread over more capacity.

Long-Term Effectiveness in Reducing Congestion

Rating: Medium. In the longer term, the effects of triple convergence will tend to erode any short-term traffic relief that occurs in the general-purpose lanes. On the other hand, the fact that toll prices are used to manage the demand for the HOT lanes means that they will continue to provide optimal flow conditions. (If demand for traveling in the HOT lanes increases over time, as is often the case, then the price for using the lanes will rise as well.)

Mobility, Accessibility, and Traveler Choice

Rating: Very good. HOT lanes benefit drivers by providing additional travel options. When speed and travel-time reliability are important—for example, if a driver needs to make it to a meeting on time or to pick up a child from day care—it is possible to pay the toll or form a carpool in order to use the HOT lanes. For trips with a lower level of urgency, drivers can continue to use the more congested lanes for free. Analysis of existing HOT lanes suggests that many regular users choose to pay the toll for faster and more reliable travel a few times each week rather than for all trips (Sullivan, 2000), so the optional nature of HOT lanes appears to be a compelling benefit.

Note that buses are typically allowed to use HOT lanes as well, so the quality of transit service in a region can also be enhanced by implementing HOT lanes.

Safety

Rating: Bad/can partially mitigate—>neutral. HOT lanes are separated from general-purpose lanes by using either a soft or a hard barrier. Installing this barrier can reduce the width of shoulder areas, creating safety issues when vehicles must pull over for emergency or enforcement reasons. To the extent that highways can be widened to accommodate HOT lanes, these effects can be mitigated.

Turbulence in the general-purpose traffic stream may also occur at HOT-lane ingress and egress points, where vehicles need to change lanes. This effect can be partially mitigated by limiting the number of access points to encourage longer-distance trips in the HOT lanes with less-frequent merging.

Economic Efficiency

Rating: Good. HOT lanes, one form of congestion pricing, offer the potential to improve the efficiency with which roads are used, specifically by increasing throughput in the priced lanes. During peak hours on the SR-91 facility, for example, total vehicle throughput for the two priced lanes is about the same as that for the four free lanes; in other words, each priced lane accommodates twice as many vehicles per hour as each free lane.

In economic terminology, the capacity improvement is achieved by internalizing (i.e., by charging a price associated with) one of the common externalities associated with driving—the costs of congestion imposed on others. Attaching an explicit price for travel in peak hours helps manage demand so as to maximize throughput in the priced lanes. That said, the efficiency gains achievable from HOT lanes are somewhat limited because only a minority of travelers are priced and those who opt not to use the priced lanes continue to generate congestion in the free general-purpose lanes (see Small and Yan, 2001, for further discussion).

Environment

Rating: Neutral (uncertain). Vehicles traveling in free-flow conditions generate fewer emissions (and burn less gas) than vehicles traveling in heavily congested conditions. HOT lanes can therefore reduce per-mile emissions and gas consumption for SOVs that used to be stuck in the congested free lanes. On the other hand, HOT lanes effectively increase a freeway's overall capacity (especially if the HOT lanes are constructed from scratch rather than converted from existing lanes), and, over time, this will result (through the effects of latent and induced demand) in more total cars using the corridor. These two effects tend to trade off against one another, leading to an environmen-

tal rating of *neutral*. We note, however, that the net outcomes may vary from one implementation to the next, depending on project-specific details, so we also describe the rating as *uncertain*.

Equity

Rating: Neutral. Initially, many people (including some transportation-policy specialists) believed that HOT lanes would strictly benefit wealthier travelers who can afford to pay for their use. This view has declined significantly since the introduction of the 91 Express Lanes and the I-15 HOT lanes. Surveys of users of those facilities suggest that income is a poor determinant of who opts to pay the toll to access the HOT lanes. Rather, users from all income groups find that the increase in travel speed and reliability are worth the cost of the toll for at least some portion of their trips.

Stakeholder Concerns

Rating: Medium/difficult to address—>medium. The stakeholder groups involved in planning the 91 Express Lanes in Orange County included the county board of supervisors, FHWA, Environmental Defense Fund, the Reason Foundation, the Orange County and Riverside County Transportation Commissions, Caltrans, state legislators, local mayors and city-council representatives, and the International Bridge, Tunnel and Turnpike Association (Perez and Sciara, 2003, Chapter 7). Similar stakeholder groups are likely to participate in future HOT-lane planning activities in the region.

Advocates for carpool lanes have voiced concerns that HOT lanes will discourage carpooling by degrading carpool-lane performance and by allowing drivers to “buy” their way out of congestion rather than forming a carpool. Other groups that oppose tolls in principle view HOT lanes as an incremental step toward tolling all auto use. Proposals that seek to convert existing general-purpose lanes into HOT lanes face major challenges because some will argue that the existing lanes have already been paid for with gas-tax revenues and it is unfair to make people pay a second time for that capacity. Finally, as discussed in the preceding section, advocates for low-income individuals have, in

the past, claimed that HOT lanes are designed to benefit only wealthy travelers.

Note that, for many highways in the L.A. region, existing HOV lanes have little or no excess capacity and there is no additional room in the median to build new lanes. In such cases, the implementation of HOT lanes would require either (1) raising the carpool occupancy requirement from two or more individuals to three or more individuals so as to create excess capacity in the HOV lanes or (2) converting a current general-purpose lane into a HOT lane (for example, an existing HOV lane with no excess capacity and an adjacent free lane might be converted into a two-lane HOT facility). Either of these options is likely to raise objections from one or more of the stakeholders enumerated in the preceding section.

General Political Obstacles

Rating: Medium/can partially address—>low. Many of the stakeholder concerns identified in the previous section also represent political obstacles. Furthermore, while the revenues generated from HOT lanes help make HOT lanes more politically attractive, determining how they will be allocated among different agencies can be difficult. King, Manville, and Shoup (2007) addressed this issue in the context of Los Angeles and argued that giving revenue rights to cities with freeways would help overcome political obstacles facing road-pricing initiatives.

Institutional Obstacles

Rating: Medium/difficult to address—>medium. No single institution has the authority to dictate whether, when, and where HOT lanes are installed in Los Angeles. Instead, coordination and acceptance among city, county, regional, state, and federal agencies will likely be necessary. Moreover, enabling state legislation will likely be required as well.

Current Status in the L.A. Region

Rating: None. The HOT-lane concept, as noted earlier, has been implemented on SR 91 in Orange County as well as on the I-15 in San

Diego. To date, HOT lanes have not been developed in L.A. County. As of this writing, however, the Metro board of directors recently voted to accept more than \$200 million in funding from USDOT to develop HOT lanes and augment express bus service on the 10, 110, or 210 freeways, though the plans are still in their formative stages.

Interaction with Other Strategies

HOT lanes could work well with efforts to improve transit (see Appendixes B24, B25, and B26). Transit buses that use the freeway system may be allowed to access HOT lanes, thereby significantly improving transit travel times and reliability. Furthermore, revenues raised from HOT lanes may be allocated toward transit improvements.

The potential interaction of HOT lanes with ride-sharing (see Appendix B11) depends on the type of HOT lanes implemented. When carpool lanes are converted to HOT lanes, carpooling incentives might diminish as more users load into the converted carpool lanes and travelers face an additional travel option—namely, driving alone and paying a toll to access a HOT lane. When HOT lanes are added as new capacity or through the conversion of existing general-purpose lanes, carpooling is more likely encouraged.

Cordon Congestion Tolls

Cordon congestion tolls (also described as *cordon pricing programs*) represent a form of road pricing intended to reduce traffic in dense urban areas, such as city centers or CBDs. The term *cordon* refers to a clearly demarcated geographic boundary that surrounds the tolling area, and vehicles that either cross the boundary or drive in the cordon area during peak travel hours are subject to the toll. In the simplest case, the tolling program may involve a flat charge that applies during weekday business travel hours (e.g., 7:00 a.m. to 6:00 p.m., Monday through Friday) and would not apply at other times. In more sophisticated programs, the tolls may vary by the specific time of day (e.g., higher at 8:00 a.m. than at 10:00 a.m.), by vehicle class (e.g., higher for a commercial truck than for a passenger automobile), and by the specific point of entering the cordon area (e.g., higher along the busiest thoroughfares than on less crowded streets). Most cordon tolls currently in existence are centered on CBDs, but there has also been talk of extending the concept to other activity centers, such as airports.

Cordon pricing has the potential to reduce traffic congestion in the cordon area while generating substantial revenues. It is generally regarded as being most appropriate for areas where road capacity is limited, demand for travel is substantial, and drivers have the opportunity to either switch to other modes (such as transit) or shift their travel schedules toward off-peak hours when tolls are lower.

Variations on the cordon-pricing theme have been implemented in other countries, including well-known examples in London, Stockholm, and Singapore. In the United States, San Francisco is currently

evaluating the potential for implementing a cordon toll; New York also recently developed a proposal to implement cordon tolling, but the plan failed to receive approval from the state legislature.

Evaluation of Strategy

Cost/Revenue Implications

Rating: High revenue. Cordon congestion toll revenues depend on a variety of factors, such as the size of the area subject to tolling, the density of traffic in that area, and cordon toll rate applied to drivers. In general, though, these programs can generate significant revenues—in the tens or hundreds of millions of dollars per year. According to a recent report from the European Conference of Ministers of Transport, for example, annual revenues (converted to U.S. dollars) from the London, Stockholm, and Singapore cordon tolls are approximately \$385 million, \$110 million, and \$55 million, respectively. It should be noted that the cost of implementing and administering cordon congestion tolls is high, with annualized capital plus operating costs ranging between 40 and 55 percent of annual toll revenues for these same three examples (ECMT, 2006). Even with such high costs, however, the net revenues are still significant, providing an ongoing source of funds that can be invested in road and transit improvements.

Short-Term Effectiveness in Reducing Congestion

Rating: High. Evidence from existing cordon-pricing schemes suggests that this strategy can be extremely effective in reducing traffic—especially for trips in the charging zone, but also for trips leading into the charging zone. For example, when Singapore first introduced a manually implemented cordon congestion toll (known as the area licensing scheme [ALS]) in 1972, the traffic volume in Singapore's CBD dropped by 45 percent (Goh, 2002). In 1998, Singapore replaced the ALS with a more sophisticated electronic road-pricing (ERP) program that relies on new electronic tolling technologies to implement both facility-based and cordon congestion tolling elements. Within a year of introducing the new ERP scheme, overall traffic volumes in

the city decreased by 15 percent on a daily basis and by 16 percent in the morning peak hours (Fabian, 2003). On the expressways leading into the CBD, travel speeds have improved from 45 to 65 kilometers per hour (km/h), while, in the CBD, they have nearly doubled to 36 km/h. Average bus speeds have also increased by 16 percent due to reduced congestion levels (Goh, 2002). With the introduction of London's cordon congestion toll, total VMT in the CBD has been reduced by 15 percent, while the level of congestion (measured as the difference between congested travel times and free-flowing travel times) has dropped by 30.5 percent. Correspondingly, travel speeds in the charging zone have increased by 21 percent, while travel times from outer to inner London have been reduced by 12 percent. Average bus speeds have remained relatively constant, but the amount of schedule delay in the charging zone typically caused by congestion has been reduced by 33 percent (Santos and Shaffer, 2004).

It should be noted that the overall effectiveness of cordon congestion tolls is sensitive to the level at which the toll is set. If the London or Singapore toll rates were set to a lower level, for instance, the effects on congestion would have been less pronounced. Provided that the tolls are set appropriately, however, cordon pricing can be very effective in relieving congestion, as demonstrated by the statistics cited earlier.

Long-Term Effectiveness in Reducing Congestion

Rating: High. Over time, as people become accustomed to paying a cordon congestion toll (and perhaps come to value more highly the reductions in delays that result from the toll), more travelers may become willing to pay the necessary charge. This effect was observed, for instance, in the years that followed the initial introduction of the ALS in Singapore (Phang and Toh, 1997). As more travelers choose to pay the congestion toll, the benefits from the program will slowly erode. This effect can be easily countered, however, by raising the toll as needed to maintain the desired level of congestion relief. For example, the London toll was initially set to a daily rate of £5 but has subsequently been raised to £8, in part to maintain the program's effectiveness.

Mobility, Accessibility, and Traveler Choice

Rating: Bad/can be partially mitigated—>neutral (uncertain).

Unlike HOT lanes, which provide drivers with a choice between free travel in the slower general-purpose lanes and paying a toll for faster and more reliable travel speeds in the priced lanes, cordon congestion tolls are mandatory, applying to all drivers who enter the cordon area. The mandatory nature of cordon tolls has negative implications for mobility, accessibility, and traveler choice. Absent the tolls, many travelers would prefer to drive during the peak hours, even if they must suffer through congested road conditions to do so. Once the tolls are applied, however, at least some travelers will switch to options that they consider less preferable in order to reduce the tolls that they must pay. Some may shift to other modes, such as transit or carpooling; others may alter travel times to avoid the charging hours. Still others may change the destinations of their travel or choose to forgo their trips altogether. When the ALS was first introduced in Singapore, the transit commute share more than doubled, increasing from 33 percent to 69 percent (Phang and Toh, 1997). Following the introduction of the ERP program in Singapore, transit ridership increased again, while the level of traffic entering the CBD between 7:00 and 7:30 a.m.—just before the charges applied—increased by 11 percent (Fabian, 2003). After the London congestion toll was established, the number of automotive journeys into the CBD decreased by 31 percent, while the number of trips by bus increased by 33 percent and the number of trips by bicycle increased by 31 percent (Santos and Shaffer, 2004).

On the positive side, by reducing congestion on city streets, cordon congestion tolls can lead to improved travel speeds for buses and ride-share vehicles, among others. This creates mobility and accessibility improvements for travelers already relying on these modes before the charging program was initiated. At the same time, for those drivers who place a higher value on travel time than on the cost of tolls, the reduction in congestion resulting from cordon congestion tolls may also represent improvements in mobility and accessibility. That said, drivers far outnumber transit users and carpoolers in Los Angeles, and lower- and moderate-income drivers (who will tend to place a higher value on the monetary costs of travel) outnumber wealthier drivers (who will tend to

place a higher value on travel-time savings). For these reasons, the negative consequences of cordon congestion tolls for mobility, accessibility, and traveler choice are likely to outweigh the positive consequences.

Cities can mitigate the negative mobility and accessibility effects of cordon tolls, at least to some extent, by using some portion of the considerable revenue stream to invest in public-transportation improvements in the vicinity of the cordon area. This strategy has been pursued, for example, in both the London (TfL, 2007) and Singapore (Goh, 2002). The ability to reinvest cordon toll revenues to make dramatic improvements in transit leads us to modify the overall rating to *neutral* for mobility, accessibility, and traveler choice.

It is unclear, however, how effectively this strategy would work in Los Angeles. The cities in which cordon tolls have been implemented to date are relatively monocentric in form and already have very effective transit systems that provide good service to the crowded downtown areas. Los Angeles, in contrast, is quite polycentric, and, while its transit system is effective in certain areas, it is still poorly developed in others. Moreover, many employees in the region face long commutes on a daily basis. It could still be many years, therefore, before a large percentage of L.A. residents could opt for transit as an effective replacement for traveling by car. Given these concerns, which certainly merit additional investigation, our modified rating of *neutral* on this issue is noted as being *uncertain*.

Safety

Rating: Good (uncertain). Cordon congestion tolls appear to improve safety outcomes in the charging area itself. Since the London toll began, there has been a 20-percent decrease in the number of accidents in the CBD during charging hours (TfL, 2004). Accidents involving bicyclists and motorcycles, meanwhile, have decreased by 17 percent and 15 percent respectively, even though their mode shares have risen considerably (Santos and Shaffer, 2004). The safety effects outside the charging area are unclear, leading us to describe this rating as *uncertain*.

Economic Efficiency

Rating: Very good. Cordon pricing has the potential to induce more-efficient travel behavior by forcing drivers to internalize the external costs (specifically, the costs of congestion imposed on others) associated with driving. It should be noted, however, that the degree of improvement in this area is quite sensitive to the structure of the charging program. For example, programs that charge a single toll per day regardless of the number of times that a vehicle enters or exits a zone are less effective in accurately reflecting externalities than programs that charge additional tolls each time a vehicle crosses the cordon boundary. Likewise, programs that charge a single toll rate regardless of vehicle class or time of day are less effective than programs in which the toll rate can vary at different times of day or for different categories of vehicles. Finally, it should be noted that the charge level can be set too high. For instance, one could envision a very high toll that would reduce traffic by 80 or 90 percent. While this would eliminate all traffic concerns in an area, the economic costs—in terms of the social value that the foregone trips would have provided—could greatly exceed the benefits in terms of reduced congestion and emissions. This highlights the need to perform careful economic analysis in determining the structure and level of tolls that visitors to the cordon area must pay.

Environment

Rating: Good (uncertain). Cordon pricing is likely to improve local air quality in the cordon area by reducing auto travel. In London, for example, ambient levels of nitrogen oxides and particulate matter in the charging zone have decreased by about 12 percent, while fuel consumption and greenhouse-gas emissions by travelers to the zone have decreased by 20 percent and 19 percent, respectively (TfL, 2004). The environmental effects of cordon tolls outside of the charging area are less clear, however, and thus we characterize our rating of *good* as being *uncertain*.

Equity

Rating: Very bad/can partially mitigate—>bad. Researchers studying cordon pricing have focused on how the strategy will affect

individuals based on their income levels and where they choose to live, work, and travel. Many transportation analysts and decisionmakers have expressed concern that cordon-pricing schemes are likely to disadvantage lower-income commuters who rely on their automobiles to get to work. Such individuals already must dedicate a larger share of their income to transportation than do other members of society, and their jobs may provide less flexibility to shift work schedules in order to avoid peak-period cordon tolls. While some lower-income commuters could shift to transit to minimize the burden of the toll, others either live in areas that transit does not yet well serve or must engage in lengthy commutes that would take much too long via transit. Cordon congestion tolls also raise equity concerns related to geographic considerations. For instance, those who live outside a cordon area and must pay a toll to enter the charging zone for employment are likely to face a higher burden than those who already live and work inside the cordon (in some cases, the toll is charged only for those who cross a boundary of the cordon; in other cases, the charge also applies for driving in the charging zone, but local residents receive a discount). Some researchers have pointed out, however, that such equity concerns can be at least partially mitigated through revenue-redistribution schemes—such as investing in improved transit options—intended to benefit those who are most disadvantaged by the toll charges.

Stakeholder Concerns

Rating: High/difficult to address—>high. Stakeholders are likely to voice at least several concerns. First, some fear that cordon congestion tolls will violate the right to privacy by documenting individual travel behavior patterns. Second, as discussed in the preceding section, certain jurisdictions, based on their geographical relationship to the charging area, may argue that the cordon toll will disadvantage their residents. Third, commercial establishments in the charging zone, such as retailers and restaurants, may argue that a cordon toll will reduce their customer traffic. This concern was raised following London's implementation of cordon pricing, although little empirical evidence suggests that businesses located in the cordon were actually disadvan-

taged. Finally, firms that must deliver goods into and out of the cordon area may oppose the high costs of paying the toll on a frequent basis.

General Political Obstacles

Rating: High/can partially address—>medium. Political support among voters and elected officials for an aggressive road-pricing policy like cordon pricing is not likely to be strong. Beyond the specific equity and stakeholder concerns already discussed, some may argue that pricing existing road infrastructure is inappropriate because citizens have already paid for the capacity through gas taxes and other transportation revenue instruments. Others may simply resist what they perceive to be a new form of taxation as a matter of principle. Evidence from other cordon-pricing implementations suggests, however, that a commitment to reinvest cordon toll revenues into local transportation improvements—for both roads and transit—can help overcome this opposition, at least to some extent (Sorensen and Taylor, 2005b).

Institutional Obstacles

Rating: High/can partially address—>medium. Cordon tolls could be fully implemented within a single city's jurisdictional boundaries. Even so, the cooperation among multiple agencies would likely be required. For example, if the City of Los Angeles were to implement a cordon toll surrounding the downtown business district, Metro would need to be involved in any effort to plan and implement transit improvements in the cordon area. Caltrans and FHWA participation might also be required, as those agencies have jurisdiction over the freeways that run through the downtown area. Despite the multi-jurisdictional cooperation required, however, the prospects for establishing pricing programs in the L.A. context have improved in recent years. The City of Los Angeles, Metro, and SCAG are all currently investigating the potential for alternative forms of road pricing in the region, and thus they may be more willing to work together on this issue. USDOT, through its Value Pricing Pilot and Urban Partnerships programs, is also encouraging the development of alternative forms of road pricing.

Current Status in the L.A. Region

Rating: Limited. The PierPASS program (PierPASS, undated) at the Ports of Los Angeles and Long Beach is conceptually similar to a cordon congestion toll. Under PierPASS, whenever a truck picks up or drops off a loaded container at the ports during peak business hours (3:00 a.m. to 6:00 p.m. weekdays), the receiving cargo owners (shippers, consignees, or their agents) must pay a traffic-mitigation fee of \$50 per TEU or \$100 for any larger containers. If a truck picks up or delivers a container during off-peak hours (6:00 p.m. to 3:00 a.m. Monday through Thursday or 8:00 a.m. to 6:00 p.m. Saturday), the traffic fee is not required. This provides a direct financial incentive that helps reduce truck traffic in and around the ports during the busiest hours of the day.

Cordon congestion tolls that apply to all drivers—private as well as commercial vehicles—have yet to be implemented in the L.A. region. The strategy is, however, receiving an increasing level of attention. As noted earlier, several local jurisdictions and agencies are currently investigating the potential for applying various forms of congestion pricing in the region. One challenge that makes the application of cordon tolling in Los Angeles more difficult is the city's polycentric structure. Most of the cities where cordon tolls have been applied to date, such as London, Singapore, and Stockholm, are relatively monocentric. In contrast, business activity in Los Angeles is quite dispersed; Giuliano and Small (1991), for instance, identified 32 distinct activity centers in the region. The polycentricity of Los Angeles makes it more difficult to determine the best location, or locations, for the application of cordon congestion tolls.

Interaction with Other Strategies

Cordon pricing can be made more attractive by coupling it with strategies that seek to improve public-transportation options into and out of the cordon area (see Appendixes B24, B25, and B26). In fact, the revenue from cordon tolls can fund many of these improvements. In so doing, many of the mobility concerns raised by opponents of cordon tolls can be addressed.

Variable Curb-Parking Rates

Introduction

If parking spaces at the curb are underpriced relative to demand, on-street parking becomes extremely scarce, creating a situation in which drivers must circle around from one block to the next to find an elusive free space. This phenomenon is often described as *cruising for parking*. Cruising wastes both time and fuel, and it also creates considerable congestion in retail districts with chronic parking shortages. There is a simple remedy for this problem: charging market rate prices for curb parking—that is, rates that are high enough to ensure that there will usually be one or two free spaces on every block such that a driver looking for parking will be able to quickly find a space without cruising (Shoup, 2005). Because the demand for parking typically varies by location and time of day, the market-rate price for parking will also vary by location and time of day; hence the term *variable curb-parking rates*.

Local retailers concerned that higher peak-hour rates will drive customers away may oppose charging market rates. While it turns out that this concern is unsubstantiated, it remains politically salient. To alter the political calculus and enlist more support from the retail community, cities can agree to return parking-meter revenues to the districts in which they are generated, allowing the money to be used for public improvements that will make the districts more attractive to shoppers. These areas, often referred to as *parking-benefit districts* (Shoup, 2005), can make the concept of variable curb parking rates

even more compelling. Though it is possible to implement one without the other, we discuss the two together in this strategy discussion.

Why Parking Time Limits Do Not Help

The prevalence of underpriced curb parking is not surprising. All else equal, most drivers would prefer to park for free, so elected leaders—ever mindful of the next election cycle—tend to be reluctant to raise curb-parking rates. In the city of Los Angeles, for example, more than 80 percent of the meters have not had rate increases in the past 17 years (Jeff, 2007b). Instead of charging market rates for curb parking, many cities instead impose parking time limits to increase the parking turnover rate. Yet this approach has its own share of drawbacks (Shoup, 2005; Zack, 2005). First, time limits are difficult to enforce, and local employees—who have the advantage of being in the area every day and thus can observe the patterns and rhythms of parking-enforcement patrols—often find ways to game the system—for example, by rotating spaces with one another on a periodic basis. Second, enforcement is expensive, and the city earns income only by issuing and recovering violation fines—a politically unpopular revenue source with high collection costs. Third, and on a related note, active enforcement of time limits creates significant driver hostility, and there have been many stories of frustrated parkers verbally and even physically assaulting parking-enforcement officers. Fourth, time limits are economically inefficient, in the sense that they force visitors to leave an area even if they would be willing to pay more to stay longer—perhaps to do a little more shopping or dine at a local restaurant. Fifth, and most important from the perspective of traffic congestion, time limits do little to reduce the incentive to cruise for parking. Although time limits may stimulate some additional turnover at the curb, if the actual price of parking remains below the market rate, demand will still exceed supply. This makes it difficult to find an open space, thus encouraging drivers to cruise for parking.

Negative Consequences of Underpriced Curb Parking

Because underpriced curb parking is prevalent in most metropolitan areas, many people are quite accustomed to cruising, while unaware

of the negative unintended consequences. As it turns out, the problems associated with cruising are unexpectedly severe. UCLA planning professor Donald Shoup (2005) conducted an elaborate study on cruising for parking in Westwood Village, a district adjacent to the UCLA campus, in the late 1980s. At the time of the study, the parking supply in Westwood consisted of 470 curb spaces spread among 15 blocks, with another 3,400 off-street spaces. The meter rate for on-street spaces was \$0.50 per hour during the day, and parking was free after 6:00 p.m. In contrast, the prevailing fee for privately operated lots was \$1 per hour during the day, with a flat rate of \$2 to \$3 for evening parking after 6:00 p.m. At any time of day, then, parkers had a direct financial incentive to cruise for the underpriced street parking rather than pay the higher off-street rates.

To examine the effects of underpriced curb parking in Westwood, Shoup and his students spent many hours observing the turnover rates for on-street spaces and circling blocks to observe how long, on average, it would take for a car to find an available space at different times throughout the day. By extrapolating the findings of these experiments, Shoup calculated that cruising for curb parking in the 15 blocks of Westwood, over the course of a year, would result in 945,000 excess miles of travel—enough to travel to the moon and back, twice—along with 47,000 gallons of wasted fuel and several hundred tons of carbon-dioxide emissions. In addition, Shoup calculated that, during the peak cruising period, around 6:00 p.m. (when on-street parking became free), more than 90 percent of the cars traveling through Westwood were actually circling for parking. Over the course of an entire day, the average volume of cars cruising for free spaces was just under 70 percent. Though the Westwood case is perhaps somewhat extreme, the findings are not aberrant. As Shoup noted, similar studies in other large cities, such as Washington, D.C., New York, San Francisco, London, and Sydney, have shown that cruising for underpriced street parking accounts, on average, for about 30 percent of the traffic in retail districts, ranging up to 74 percent in one of the studies.

Implementing Performance Curb Parking

All of the problems associated with cruising—additional traffic, wasted time and fuel, and harmful emissions—can be eliminated simply by charging market rates for curb pricing. Shoup (2005) defined market rates as a price level that results in an average occupancy rate of about 85 percent. This would mean that, on a block with 10 curb spaces, there would usually be one or two free spaces such that a driver looking for parking could find a space without cruising. If the occupancy rate exceeds 85 percent, the parking rate should be increased; if it falls below 85 percent, the rate can instead be reduced. An interesting ancillary benefit of market-rate curb pricing is that it eliminates the need for setting parking time limits. As long as the prices are high enough to ensure one or two free spaces on every block, there is no reason to be concerned about how long an individual vehicle stays, because there will be still be other spaces available.

Because the demand for curb parking varies by both location and time of day, market-rate curb pricing must exhibit similar variations. In other words, prices on one block may be higher than another, and the hourly rates at noon on a weekday may differ from the hourly rates at 8:00 p.m. Yet the pricing scheme can be effective without being overly complex. For example, Redwood City, located in the San Francisco Bay Area, recently enacted a policy of pricing curb-side parking at market rates, which is depicted in Figure B20.1. For less-convenient street parking (the yellow roads), Redwood City charges \$0.25 per hour from 10:00 a.m. to 6:00 p.m., Monday through Friday. For more-convenient street parking (the orange roads), Redwood City charges \$0.50 per hour from 10:00 a.m. to 6:00 p.m., and the charges apply on Saturday as well as the week days.

Over time, as demand patterns change, it will likely prove necessary to alter the parking rates on a periodic basis in order to maintain the 85-percent occupancy goal. This will create political difficulties if elected officials are required to approve each increase in parking charges. To overcome this dilemma, cities that wish to implement performance curb parking can develop an ordinance that (1) sets a target occupancy rate of 85 percent and (2) allows rates to vary as needed to maintain the target occupancy goal without approval of elected

Figure B20.1
Variable Curb-Parking Fees in Redwood City, California



SOURCE: City of Redwood City (undated). Used with permission.

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officials, based on periodic surveys (such surveys, which might occur every three months or so, can be conducted manually, or they can be automated using new smart parking-meter technology that records parking occupancy). This approach, which was used in Redwood City, will ensure that parking prices remain a function of demand rather than of political will (Zack, 2005).

Effects on Retail Patronage

Local retailers are often concerned that market-rate parking prices will drive potential customers away. In fact, the case turns out to be quite the opposite; performance curb parking can bring *more* visitors to an area (Shoup, 2005). To explain why, it is first useful to point out the obvious fact that charging less than market rates cannot increase the number

of cars parked at the curb because it cannot increase the number of spaces available. Rather, underpriced parking creates a chronic *shortage* of available parking that has the effect of deterring visitors.

Market-rate curb prices, in contrast, act to increase the number of visitors to a retail district. Because the most convenient parking spaces will also have the highest prices, local employees and other long-term parkers will seek cheaper parking in other locations—perhaps in off-street facilities or several blocks away from the main retail district. This leaves a greater percentage of the most convenient spaces available for short-term visitors, such as shoppers and diners, who will spend money in the district. The higher parking rates will also encourage some visitors to reduce the length of their stays, thereby promoting faster turnover (and more total visitors) at the curb. Other visitors, in contrast, will be more likely to carpool—upping the aggregate ratio of visitors per car—so that they can split the parking fees. Finally, market rates will ensure that a few convenient spaces are always available, so concern about parking availability will not deter potential visitors. The net effect of all of these outcomes is to increase overall patronage for a retail district (Shoup, 2005; Zack, 2005).

Despite this logic, some retailers may remain concerned that customers just do not like to pay (or to pay much) for parking. While this may be true, recent survey results from Burlingame, another town near San Francisco, suggest that a majority of parkers worry more about the convenience of parking or about whether they will receive a ticket for staying too long in a time-limited space than they do about parking-meter rates (Zack, 2005). Though market-rate pricing may lead to higher parking charges at the curb, it eliminates more-pressing concerns about the ability to find a convenient space or the need to depart within an arbitrary city-imposed time limit so as to avoid a penalty.

Returning Meter Revenues to Local Parking-Benefit Districts

Though market-rate pricing reduces congestion and enables more visitors to patronize retail districts, some business owners may doubt the legitimacy of these benefits and resist calls for change. To overcome such opposition, cities can offer to return a portion of the parking-meter revenues raised in each retail district to local business owners,

who, in turn, can use the money to invest in public improvements—such as cleaning sidewalks, planting street trees, or purchasing new street furniture—that will increase the district’s attractiveness. When local retailers recognize that the parking revenues will directly benefit their neighborhood, rather than disappearing into a city’s general fund, they become much more likely to embrace market-rate curb pricing (Shoup, 2005).

The concept of parking-benefit districts was pioneered in Pasadena in the 1990s. Between the 1930s and 1980s, the district now called Old Pasadena experienced a slow but steady decline, devolving from a thriving commercial center to the city’s low-rent district. Prior to 1993, there were no parking meters in Old Pasadena. Rather, parking was managed by two-hour time limits, though many of the on-street spaces were still taken by local employees who periodically rotated parking spaces so as to avoid being ticketed. Sensing that a chronic lack of parking might be preventing many potential customers from visiting Old Pasadena—thus contributing to the area’s continuing financial struggles—some local business owners lobbied for the installation of new parking meters to stimulate higher parking turnover. Other owners, however, feared that the imposition of parking fees might encourage the district’s existing customer base to visit other shopping venues with ample free parking instead.

Debates about whether to install new meters dragged on for two years, until the City agreed to return all meter revenues to pay for public investments in Old Pasadena. Local merchants then began to view meters as a new source of revenue, and the desire for public investments soon outweighed the fear of driving customers away. Business owners agreed to install the meters, setting an unusually high rate of \$1 per hour and operating the meters during the evenings and on Sundays as well (Shoup, 2005).

Once the meters were in place, the local merchants were able to borrow \$5 million to finance the Old Pasadena Streetscape and Alleyways Project, with meter revenues dedicated to repaying the debt. The bond proceeds paid for street furniture, trees, tree grates, and historic lighting fixtures throughout the area. Previously dilapidated alleys were transformed into safe, functional walkways with access to shops and

restaurants. By 2001, eight years after the program was initiated, Old Pasadena's 690 meters were yielding a net return of \$1.2 million per year. Of this, about \$450,000 was used to help repay the bond issue, with the remainder devoted to additional services, such as increased police foot patrols, sidewalk and street maintenance, and marketing services. With this money, the Old Pasadena Business Improvement District can now pay for daily sweeping of the streets and sidewalks, trash collection, removal of decals from street fixtures, and regular steam cleaning of the sidewalks. Over time, public improvements in Old Pasadena have translated to dramatically improved retail performance as well. In 1989, Old Pasadena had the lowest sales-tax revenue of all Pasadena's retail districts. By the late 1990s, it had the highest sales-tax revenue, surpassing other popular areas, such as the Playhouse District, Plaza Pasadena, and South Lake (Shoup, 2005).

In Old Pasadena, one of the reasons that the city agreed to return revenues to local businesses for public improvements was that the meters had not previously existed. As a result, Pasadena did not lose any of its existing parking revenues. But what of districts where parking already exists and where current revenues are used to support a city's general fund? In such cases, cities would be understandably reluctant to return all meter revenues to local districts, as this could have a negative effect on the city's overall budget. With market-rate prices, however, total revenues will generally increase, so there should be room for compromise. It may be possible, for instance, for cities to claim the current level of revenues and allow local commercial districts to claim any additional revenues that result from the imposition of market-rate prices. Both Redwood City and the City of San Diego have implemented variants on this theme (Shoup, 2005; Zack, 2005).

Evaluation of Strategy

The evaluations presented here assume that performance curb parking and parking-benefit districts are pursued jointly.

Cost/Revenue Implications

Rating: High revenue. Based on the Pasadena experience, it is not unreasonable to expect that the implementation of market-rate pricing for curb spaces could generate more than \$1 million per year in a single retail or entertainment district. If implemented across all such districts in the greater L.A. region, net proceeds could easily total in the tens, if not hundreds, of millions of dollars annually. Additionally, if some portion of the proceeds is reinvested in public-amenity improvements in and around retail districts, the level of commercial activity will likely increase as well, leading to enhanced sales-tax revenues for local jurisdictions.

Short-Term Effectiveness in Reducing Congestion

Rating: Medium. The studies examined by Shoup (2005) suggest that performance curb parking, by virtue of eliminating the need to cruise for available spaces, could reduce an average of about 30 percent of the traffic flow in busy retail districts. In the peak travel hours for very busy districts—such as Westwood Village in its late 1980s heyday—market-rate pricing could eliminate more than 90 percent of the traffic flow. It can be argued, therefore, that market-rate prices for curb parking can have a very strong effect in reducing traffic in activity centers. The strategy has less of an effect, however, on regional traffic patterns and the level of congestion on arterials and highways. For this reason, we have assigned the strategy an overall rating of *medium* in terms of short-term congestion reduction.

Long-Term Effectiveness in Reducing Congestion

Rating: Medium. With performance curb parking, prices are raised over time, as needed, to maintain the target occupancy rate of 85 percent. As a result, the initial benefits are sustainable over time. Unlike many of the other strategies considered, the effectiveness of market-rate curb pricing—at least in the activity center where it is implemented—is not subject to erosion based on the phenomenon of triple convergence.

Mobility, Accessibility, and Traveler Choice

Rating: Good. Aside from significant congestion-related benefits, charging market rates for curbside parking effectively increases the parking options available to drivers as well. When curbside parking is underpriced, a neighborhood quickly becomes overcrowded. As a result, even though a few lucky drivers may find a spot when they first arrive, most will have to spend some time cruising for parking. And while the space that they eventually find may be cheap, there is no guarantee that it will be convenient. Once market-rate prices are established, drivers can select among different parking alternatives, depending on their preferences. Longer-term parkers, for instance, along with others interested in reducing their parking fees, can choose cheaper parking alternatives located several blocks away from their intended destinations. Meanwhile, shorter-term parkers, along with those more concerned with convenience than cost, can choose to pay higher hourly rates for more-desirable parking locations. No one, however, will need to cruise to find a space.

Safety

Rating: Good. Shoup (2005) argued convincingly that charging market-rate prices for curbside parking will yield important safety benefits for drivers as well as cyclists and pedestrians. When curbside parking is underpriced and, as a result, scarce, drivers cruising for parking must devote considerable attention to scanning the sides of the road for available spaces. They are thus less likely to be watching other drivers, cyclists, or pedestrians on the road. In addition, drivers searching for parking will often stop or veer suddenly when they see a space about to be vacated, creating a hazard for others on the road. Research findings suggest, in fact, that between 40 and 60 percent of all midblock accidents involve parking (Weant and Levinson, 1990). When market rates are instituted, in contrast, one or two spaces will usually be available on every block. This means that drivers can spend more time focusing on other traffic and less time looking for spaces, making the road safer for all parties.

Economic Efficiency

Rating: Very good. Charging market rates for curb parking performs well with respect to economic efficiency: It allows the mechanism of pricing to allocate a scarce resource—parking at the curb—to those who value it most. Those who place a higher level of importance on time and convenience can pay higher prices for the most convenient spaces, while those who place a higher value on cost can opt for cheaper, if slightly less convenient, parking alternatives. In addition, the implementation of market-rate curb prices eliminates the congestion, wasted time, and wasted fuel associated with cruising for parking, an activity that adds no social value.

Environment

Rating: Very good. By reducing the wasted travel associated with cruising for parking, market-rate prices for curb parking can result in significant environmental benefits. As suggested earlier, cruising for parking in Westwood Village generates several hundred tons of excess carbon-dioxide emissions annually, and the effects are likely similar in other retail districts throughout Los Angeles. Widespread implementation of market-rate prices for curb parking would eliminate such excess emissions.

Equity

Rating: Neutral. With market-rate curb pricing, lower-income drivers would have the hardest time paying for the most convenient spaces. On the other hand, they would still have the alternative of paying less for parking a few blocks away from the prime sites; in other words, paying a high price for parking becomes an option rather than a requirement. In addition, lower-income drivers (like everyone else) would no longer have to waste time and fuel looking for an available spot to park. Taking all of these factors into consideration, we have selected a rating of *neutral* for equity effects.

Stakeholder Concerns

Rating: Medium/can be fully mitigated—>low. As noted, local merchants may initially oppose market-rate pricing for curb parking

out of concern that higher parking charges would drive away potential customers. This proves not to be the case, but the fear may nonetheless engender stakeholder opposition. To overcome such concerns, cities can create parking-benefit districts in which some portion of the meter revenues raised in each retail district is returned to the district for investment in improved public amenities. As shown in the case of Old Pasadena, the promise of new revenues can effectively sway resistant merchants' opinions to favor increased meter rates, and the resulting revenue stream can, over time, transform a district into a much more desirable destination, leading to significant growth in retail activity.

General Political Obstacles

Rating: Low. All else equal, no one wants to pay more for parking, and market-rate curb pricing would, in many cases, lead to increased rates. On the other hand, as suggested by the Burlingame survey results mentioned earlier (Zack, 2005), the majority of parkers appear to be more concerned with such factors as convenience and the worry over whether they will receive a ticket in a time-limited space. Performance curb parking will ensure that all parkers can find a space conveniently when they need one, and it will eliminate the need to set arbitrary time limits that may not align with a particular parker's planned activities. In addition, all drivers in a retail district will appreciate the considerable reduction in traffic that results from the elimination of cruising for parking. The benefits therefore significantly outweigh the disadvantages, such that, even if there is some initial political resistance, it should dissipate quickly.

Institutional Obstacles

Rating: Medium/can be fully mitigated—>low. Standard parking-meter technology—developed originally in the 1920s—cannot support the implementation of parking rates that vary by time of day. Rather, it is necessary to replace older meters with newer technologies, such as multispace meters, and this involves both time and expense. In addition, many cities are accustomed to using parking-meter revenues to support the general fund. There may thus be institutional resistance to the idea of parking-benefit districts in which some por-

tion of market-priced meter revenues—revenues that, by precedent, belong to the city—would be returned to local merchants for their own public investments. Moreover, some administrators may perceive it to be unfair that already-popular commercial districts—which would, as a result of their success, tend to have the highest market-rate parking prices—would get more money than struggling districts, which are arguably in greater need of public investment.

Once it is recognized that market-rate curb pricing will boost overall parking revenues, it becomes possible to address all of these concerns. First, increased parking revenues can quickly pay for the new meter technology. Second, if a city depends on existing meter revenues but perceives the value in creating parking-benefit districts, the city can choose to return just a portion of the revenue stream to local merchants once market-rate curb prices have been implemented—specifically, the city can return the difference between the new level of revenues and the amount that the city had previously collected. In this way, the city will not be made worse off, and the district will still reap benefits. Third, if more popular districts have higher market-rate parking prices and thus receive more direct revenues through the institution of parking-benefit districts, they will be less in need of other forms of city investment. As a result, a city will have greater latitude to channel other public resources from the general fund to areas more in need of public investment. A final point, as illustrated in Old Pasadena, is that using meter revenues for local investments will likely lead to increased commercial activity over time, and this will boost sales-tax receipts. This also makes the city better off.

Current Status in the L.A. Region

Rating: Limited. Many cities in the L.A. region have parking rates that vary from one area to another, and some have extended the hours of metering into the evenings and on Sundays—both steps toward variable curb-parking rates. However, few cities actively manage parking rates so as to maintain a target curbside occupancy rate of 85 percent. Glendale recently adopted a policy to implement market-rate pricing along Brand Boulevard, while the City of Riverside—just east of Los Angeles—also recently voted to implement such a policy (Shoup,

2007). Old Pasadena has implemented parking-benefit districts, but this strategy likewise has yet to achieve significant penetration in the L.A. region. That said, these concepts do appear to be gathering momentum. The City of Los Angeles is currently installing new meter technology that would be capable of supporting market-rate curb pricing and has developed plans to phase in this policy in certain areas in the coming years (Jeff, 2007b).

Interaction with Other Strategies

Variable curb-parking rates can complement efforts to encourage more pedestrian (see Appendix B27) and bicycle (see Appendix B28) travel. First, by eliminating cruising for parking, this strategy makes the roadways safer for all users, including cyclists and pedestrians. Second, if parking-benefit districts are established, local merchants can use the new revenue stream to invest in public amenities that will make an area more desirable for walking and biking. Market-rate curb pricing is also synergistic with efforts to improve transit (see Appendixes B24, B25, and B26) or encourage more carpooling (see Appendixes B3, B4, and B11), as visitors will be more willing to consider these modes to avoid higher parking charges.

Parking Cash-Out

According to data from the most recent census, almost 90 percent of commuters across the county travel to work by automobile, and almost 80 percent drive alone (Pisarski, 2006). One of the reasons that so many commuters drive to work is that firms commonly offer free or heavily subsidized parking as an employee benefit (Shoup, 1997). In California, for example, approximately 95 percent of automobile commuters receive free parking (Long, 2002). Employer-paid parking is common even in CBDs, where the cost to employers of offering free parking is much higher. One survey of the L.A. CBD found that 53 percent of auto commuters received employer-paid parking (Willson and Shoup, 1990), while another study indicated that 54 percent of trans-Hudson commuters bound for the Manhattan CBD during the morning peak travel hours received subsidized parking (Port Authority of New York and New Jersey, 1984). As of the mid-1990s, employers across the United States provided around 85 million free parking spaces for commuters (Shoup and Breinholt, 1997).

All of this free parking comes at a staggeringly high cost. The Association for Commuter Transportation (1996) estimated that employer-paid parking across the nation represented an annual subsidy on the order of \$36 billion. The social costs are significant as well. Shoup (1997) described employer-paid parking as a matching-grant program for auto commuting: If employees buy their own gas and shoulder other vehicle-ownership and -operating costs, firms will pay for the parking. In many cases, the value of this matching grant far exceeds other costs associated with driving to work, especially in

crowded CBDs with high daily parking rates. By providing such a significant subsidy, employer-paid parking encourages many employees who would otherwise rely on carpooling, transit, or other alternative transportation modes to drive to work instead. This additional driving exacerbates social and environmental problems related to congestion, air quality, and greenhouse-gas emissions.

One might envision, as a possible solution to excessive auto commuting, enacting legislation that would forbid employer-subsidized parking, at least in cases in which businesses lease parking on behalf of their employees. Yet many employees highly value employer-paid parking, so such a strategy would likely raise insurmountable political objections. Another option—employer parking cash-out—can achieve the same end without generating significant opposition. With parking cash-out, firms that lease (or partially subsidize) parking on behalf of their employees must offer the cash value of the subsidy to employees who choose some other mode of transportation to work. When presented with the option of taking additional cash in lieu of free or subsidized parking, many employees will choose to give up their automobiles and find some other means of traveling to work. As described by Shoup (1997), offering commuters the option to choose between free parking and its cash value makes it clear that even free parking has an opportunity cost: specifically, the forgone cash.

Recognizing the potential social benefits in terms of reduced congestion and emissions, in 1992, the State of California passed legislation (AB 2109) requiring that parking cash-out be offered to employees at any firms that meet all of the following five criteria (Long, 2002):

- employ at least 50 persons, regardless of the number of work sites
- locate in an area that does not meet federal air-quality standards
- provide free or subsidized employee parking in leased spaces
- pay for parking separately from other building space
- reduce the number of leased parking spaces without financial penalty

For qualifying firms, California's parking cash-out law represents, in essence, a test that the employer's subsidy program must pass. Specifically, the program will pass the test if it subsidizes the alternatives to parking (such as transit, cycling, or walking) as much as it subsidizes parking; a policy will violate the law only if it subsidizes parking more than the alternatives. Any of the following examples, therefore, would qualify as acceptable under the law: eliminating parking subsidies, providing parking subsidies only for carpools, offering a choice between a parking subsidy and its cash value, or offering a commuting allowance that can be spent on any form of commuting (Shoup, 1997).

Despite this legislation's potential benefits, California has not required qualifying firms to comply with the cash-out law. Initially, some uncertainty surrounded the federal income-tax consequences of cashing out parking subsidies, but this ambiguity was subsequently resolved with the Taxpayer Relief Act of 1997 (P.L. 105-34). With this change in federal legislation, the state can now enforce the cash-out law, but, to date, it has not taken the steps to do so. While the original legislation granted ARB the authority to implement cash-out, the law does not require that ARB conduct any type of outreach or monitoring. Such activities are entirely at ARB's discretion and, to date, have not received significant funding. In addition, the law contains no reporting requirements for businesses, making it virtually impossible for ARB to assess or monitor compliance. ARB has published and made available a 10-page guide to the parking cash-out law, providing information about who is subject to the law and how to implement cash-out programs. Otherwise, ARB has conducted little outreach to make employers aware of the program, and statewide data on the effectiveness of parking cash-out are simply not available (Long, 2002).

The primary goal of this strategy, then, would be to enforce the law that already exists. With additional funding provided at the state level, ARB could certainly achieve that. Alternatively, local jurisdictions—such as AQMD or individual municipalities—could take it upon themselves to implement regulations or legislation mirroring the existing state law.

Evaluation of Strategy

Cost/Revenue Implications

Rating: Low cost. From the public-sector perspective, implementing parking cash-out regulations entails minor administrative costs. For example, the City of Santa Monica has instituted a local parking cash-out law for which the annual cost of administration is about \$250,000 (Long, 2002). On the other hand, parking cash-out increases federal and state income-tax revenues by an estimated \$65 per employee at participating firms, a result stemming from the fact that employer-paid parking benefits are tax-exempt, while parking cash-out benefits are not (Shoup, 1997).

Though the cost/revenue assessment focuses on the public sector, parking cash-out programs also impose relatively minor costs on participating firms. For employees who formerly drove to work and choose to accept the cash-out option instead, there is no net cost to the firms (in that the money saved on parking leases is equal to the amount provided as cash-out to such employees). When employers offer parking cash-out to employees who drive, however, they must also provide the same cash-out payment to employees who already relied on alternative transportation modes before the program was initiated. This raises the net cost of the program, but the added cost is usually minor—in large part because the percentage of drivers who choose not to drive when parking is provided for free is typically quite low. In a study of several firms that had recently implemented parking cash-out, Shoup (1997) estimated that the average net cost to employers (parking cash-out payments minus parking-lease savings) equaled about \$2 per employee per month. In addition, firms are likely to face some administrative costs associated with parking cash-out programs.

Short-Term Effectiveness in Reducing Congestion

Rating: Low. In the short term, aggressive enforcement of the state's existing parking cash-out law (or, alternatively, implementation of comparable regulations at the local level) would likely lead to modest reductions in traffic congestion. While available evidence suggests that parking cash-out programs are extremely effective in reducing the share

of workers who drive alone, only a small percentage of firms meet all of the criteria that would require them to offer cash-out to their employees. This limits the potential of parking cash-out as a strategy for reducing congestion in the short term.

The evidence that parking cash-out, where implemented, provides an effective incentive for employees to choose alternative modes of transportation is quite compelling. Shoup (1995) summarized the results of seven studies that compared commuting behavior either (1) before and after employer-paid parking was eliminated or (2) for matched samples of commuters with and without employer-paid parking. On average, the number of cars driven to work at firms that offered free parking was 72 per 100 employees. At firms that did not offer free parking, the number was only 53 cars per 100 employees, a 26-percent reduction.

In a follow-up study, Shoup (1997) examined the results for eight employers in the L.A. region—including an accounting firm, a bank, a government agency, a managed-care medical provider, a video post-production company, and eight law firms—that had recently implemented parking cash-out programs. Of the eight employers, which ranged in size from 120 to 300 employees, two were located in downtown Los Angeles, three in Century City, two in Santa Monica, and one in West Hollywood. The price of parking at the work sites ranged from \$36 to \$165 per month, and the employers offered several different variants on the basic theme of parking cash-out. While several simply offered the cash value of parking to their employees, two chose to subsidize public transit or carpooling more than parking, and two others reduced parking subsidies while raising ride-sharing subsidies.

The results from these changes were dramatic. Across the eight employers, the level of solo driving dropped from 76 percent to 63 percent (a 17-percent decrease), while carpooling rose from 14 percent to 23 percent (a 64-percent gain). Transit use increased from 6 to 9 percent (a 50-percent gain), while the share of walking and biking rose from about 3 to 4 percent (a 39-percent gain). Vehicle trips per employee per day decreased by about 11 percent, while vehicle commute-miles traveled (and corresponding vehicle emissions) per employee per year decreased by about 12 percent (Shoup, 1997).

Studies from other cities add further evidence of the effectiveness of parking cash-out. Long (2002), for example, described the results of a recent study of San Francisco Bay Area commuters. At firms offering free employee parking, 77 percent of workers drove to work alone, while just less than 5 percent relied on transit. When free parking was not offered, in contrast, just 39 percent of workers drove to work alone, while 42 percent made use of public transit. In short, free parking acts as a powerful stimulant to encourage driving to work, whereas the absence of free parking (or, equivalently, the option to cash out free parking) motivates a significant percentage of commuters to find other ways to commute to work.

Despite the demonstrated effectiveness of parking cash-out at firms that implement such programs, the short-term potential of this strategy for reducing congestion is ultimately limited, as mentioned earlier, because relatively few firms with more than 50 employees lease spaces on an individual basis and thus would be required to offer cash-out as an option. Several data sources support this conclusion. For example, in a recent survey of firms with more than 50 employees in Southern California, just 49 out of 217 responding firms (about 23 percent) rented rather than owned their parking spaces. Of these, the parking lease was unbundled (that is, separate from the building lease) for about 40 percent of the cases, and 88 percent of these could reduce the number of spaces leased without penalty (PRC, 1996). As a result, only about 8 percent (23 percent times 40 percent times 88 percent) of firms with more than 50 employees would be in a position to offer parking cash-out.

In certain areas in greater Los Angeles, however, the percentage may be higher. For example, the City of Los Angeles has considered the possibility of implementing parking cash-out requirements at the municipal level. As part of this effort, it has begun to collect data on the provision of parking at firms in its jurisdiction. In a recent survey of approximately 2,000 firms with more than 50 employees that pay business taxes in the city of Los Angeles, 385 respondents (or about 19 percent) stated that they provide leased parking to their employees. Of the 2,000 firms, 282 did not provide data, so the actual percentage may be even higher (Miller, 2007). Even so, the number of firms

with more than 50 employees that lease parking is still a minority of all firms (including those with fewer than 50 employees as well as those with more).

Approaching the question from a different perspective, as of October 2007, the total labor force in California was estimated at about 18,278,000, while the size of the labor force in L.A. County was estimated at 4,960,800 (CEDD, 2008). In other words, Los Angeles accounts for about 27 percent of the state's labor force. A report by the Legislative Analyst's Office (Long, 2002), meanwhile, suggests that the state's existing parking cash-out law, if strictly enforced, would apply to about 290,000 leased parking spaces statewide. If we assume that these spaces are distributed evenly based on the labor force, then about 79,500 of these—roughly 27 percent of 290,000—would be located in L.A. County. If the option to cash-out all of these spaces were offered, and if the 17-percent decrease in solo driving in response to parking cash-out observed by Shoup (1997) held constant, the net result would be a reduction of about 13,500 drive-alone commuters countywide: promising, perhaps, but—against a total employment base of nearly 5 million—not enough to achieve a major reduction in traffic.

Long-Term Effectiveness in Reducing Congestion

Rating: Medium (uncertain). Though the short-term potential of parking cash-out as a strategy for relieving congestion is limited by the relatively small percentage of firms that would be required to offer this option under current state law, the longer-term potential could be much more significant. For this to be the case, it would be necessary to institute certain policy changes that would increase the percentage of firms that are able to offer cash-out.

One option, for example, would be to apply the law to all firms, not just those with 50 employees or more. According to estimates by the California Legislative Analyst's Office (Long, 2002), this change alone would more than double the number of employees statewide with the opportunity to receive parking cash-out benefits from their employers. The motivation behind the original exemption for firms with fewer than 50 employees was to avoid imposing increased administrative costs on smaller firms. Yet firms interviewed by Shoup (1997)

indicated that the administrative requirements for parking cash-out programs were minimal and could easily be accommodated by firms of any size.

A second option would be to reform off-street parking requirements for new developments, allowing buildings at which parking is to be leased on a space-by-space basis (such that tenants could offer parking cash-out options to their employees) to qualify for reduced parking requirements. Over time, as new developments are put into place, this would slowly but steadily increase the number of firms able to participate in parking cash-out programs.

Though these two policy options could each increase the effectiveness of parking cash-out programs over the longer term, there is no guarantee that either will be implemented. We thus characterize our longer-term rating for effectiveness in reducing traffic of *medium* as being *uncertain*.

Mobility, Accessibility, and Traveler Choice

Rating: Good. Implementing parking cash-out would lead, in the short term, to slight reductions in traffic congestion, thereby contributing to slight improvements in mobility and accessibility for other road users. More importantly, though, parking cash-out effectively promotes greater choice among alternative commute options. When parking is offered for free and other commute modes are not subsidized, a large percentage of employees who might otherwise walk, bike, carpool, or use transit choose to drive instead. When parking cash-out is offered, the subsidization of alternative modes is equalized, allowing employees to choose their most preferred modes given the actual costs of each.

Safety

Rating: Neutral. By reducing the average VMT per employee, parking cash-out should help reduce auto-related accidents. On the other hand, some employees may switch from automobiles to walking or biking, and these modes have higher safety risks on a per-mile-of-travel basis (Pucher and Dijkstra, 2000). At an aggregate level, however, it is not expected that parking cash-out would have a major effect on safety.

Economic Efficiency

Rating: Very good. Parking cash-out promotes greater economic efficiency in several regards. First, it reduces the number of parking spaces required for a given number of employees. This means that, when a building is developed, a smaller share of the available space needs to be reserved for parking, while a greater share can be devoted to offer space that generates additional economic activity. Second, while other strategies intended to reduce traffic (such as cordon congestion tolls) might reduce trips to a CBD, parking cash-out simply encourages a change of mode for such trips. As such, it reduces congestion in and around a CBD without reducing economic activity there. Finally, the benefits of parking cash-out appear to significantly exceed the cost. Factoring in the social value of reducing congestion and emissions, Shoup (1997) estimated a benefit-cost ratio for parking cash-out of at least 4 to 1.

Environment

Rating: Very good. As already noted, parking cash-out programs result in significant mode-shift from single-occupant driving to other alternatives, such as carpools, transit, walking, or biking, a shift that results in fewer VMT and corresponding reductions in air pollution and greenhouse-gas emissions. In the study of eight firms in the L.A. region that had recently instituted parking cash-out programs, for instance, Shoup (1997) estimated that the resulting changes in travel behavior led to an average reduction in carbon-dioxide emissions of 367 kg (or nearly half a ton) per employee per year.

Equity

Rating: Very good. Recent national statistics indicate that women, minorities, and lower-income workers are less likely to drive to work alone (Pisarski, 2006). As a result, the benefits of employer-paid parking accrue disproportionately to wealthier white males. Parking cash-out programs correct this imbalance by providing equal commuter benefits to all employees regardless of mode choice.

Stakeholder Concerns

Rating: Low. One might imagine that employers would resist the imposition of requirements forcing them to offer parking cash-out benefits to their employees. In fact, this does not appear to be the case. To begin with, parking cash-out programs would be required only of firms that lease their parking on a space-by-space basis, and it costs such firms little to offer a parking cash-out option. Indeed, the primary effect of parking cash-out programs is to “redistribute the existing total commuting subsidy equally among all commuters, independent of the commuters’ travel choices” (Shoup, 1997, p. 208). Accordingly, the firms interviewed by Shoup (1997) praised parking cash-out for its fairness. They also stated that the parking cash-out benefit helps recruit and retain employees and that parking cash-out programs are very easy and relatively inexpensive to administer.

General Political Obstacles

Rating: Low. Parking cash-out programs do not impose additional costs on the general public, nor do they require drivers to change their behavior (rather, they provide an incentive for some employees to change their commute choices). As such, general political obstacles should be minimal.

Institutional Obstacles

Rating: Medium/can be fully mitigated—>low. The primary institutional difficulty with parking cash-out is that legislation has been passed at the state level but is simply not enforced. For local jurisdictions to implement parking cash-out requirements, they must pass local legislation that is consistent with state law yet enables local enforcement. The fact that the City of Santa Monica has instituted such an ordinance, as discussed next, demonstrates that this is possible.

Current Status in the L.A. Region

Rating: Limited. Cities in L.A. County have not yet widely adopted parking cash-out requirements, but the City of Santa Monica has. In 1990, Santa Monica enacted a TDM ordinance in an effort to reduce traffic congestion and improve air quality. Under this ordinance, firms

with 10 to 49 employees are required to attend a workshop and submit a work-site transportation plan, while those with 50 or more must designate a transportation-management coordinator and submit an annual emission-reduction plan. The plan must be based on either an employee trip-reduction plan (ETRP) or a mobile emission-reduction credit. Beginning in 1996, the City began to require all employers that would be subject to the state's parking cash-out law and that choose the ETRP option for reducing emissions to provide cash-out to their employees as part of the ETRP. If a qualifying employer does not include parking cash-out, the City will not approve the ETRP. The City's compliance rate is 100 percent, since the parking cash-out requirement is tied to the TDM ordinance. Failure to submit an approved plan results in a fine of \$5 per employee per day or, ultimately, the revocation of the business license (Miller, 2007).

Evidence suggests that Santa Monica's cash-out program has been quite effective. A 1998 survey indicated that about 30 percent of firms with 100 or more employees and about 10 percent of firms with 50 to 99 employees in the city were offering cash-out. Among the firms that offered this option, about 20 percent of employees chose to accept the cash in lieu of free parking (Long, 2002).

The City of Los Angeles is now taking steps to implement a similar measure. On August 10, 2006, Councilmember Wendy Gruel introduced a motion directing the Office of the Chief Legislative Analyst, the city administrative officer, LADOT, and the Office of Finance to explore the feasibility of enforcing the state's cash-out law. The motion also directed the chief legislative analyst and the city administrative officer to work with the Office of Finance to redesign tax forms so that the City could collect information about the numbers of employees and the provision of parking to help facilitate implementation of a cash-out program. This motion was approved on September 13, 2006, and the Office of Finance subsequently redesigned tax forms to determine (1) number of employees at firms and (2) whether they lease parking (Miller, 2007). To date, the City has not yet implemented parking cash-out requirements, but efforts in this direction are ongoing.

Interaction with Other Strategies

Parking cash-out programs provide incentives for employees who drive to work alone to choose some other mode instead. Such programs are therefore complementary with other strategies designed to increase the quality and attractiveness of other modes, such as ride-sharing (see Appendixes B3, B4, and B11), transit (see Appendixes B24, B25, and B26), walking (see Appendix B27), biking (see Appendix B28), and even telecommuting (see Appendix B12). In cases in which employers are required to implement ETRPs (see Appendix B16), parking cash-out can serve as an effective element of a comprehensive set of strategies intended to reduce the number of commutes that are made by car.

Parking cash-out also works well with employer-based car-sharing programs (see Appendix B14). One of the reasons that many commuters drive to work is so they will have access to a car, if needed, to perform errands during their lunch break. Parking cash-out represents an incentive to forgo driving to work, and the availability of car-sharing eliminates one of the reasons that might otherwise discourage employees from taking advantage of this incentive.

Finally, parking cash-out would complement congestion-pricing strategies (see Appendixes B18 and B19). Congestion pricing provides a strong financial incentive for travelers to avoid driving during peak hours. For those who are able to commute by some other mode, parking cash-out provides additional financial incentive for leaving the automobile at home.

Local Fuel Taxes

The primary motivation for implementing local fuel taxes would be to raise needed transportation revenue. Doing so, however, would also increase the cost of automotive travel and thus serve as an incentive for individuals to drive less. We thus place local fuel taxes in the same category as other pricing strategies discussed in this book: They help reduce congestion while acting as a source of local transportation funding.

Chapter Two discusses the fact that state and federal excise fuel taxes—long the mainstay of highway finance—are levied on a cents-per-gallon basis and thus need to be raised periodically to keep pace with inflation and improved fuel economy. State and federal legislators have grown increasingly reluctant to take on this politically unpopular task, however, and, as a result, real fuel-tax revenues per mile of travel have declined precipitously in recent decades (TRB, 2006). One result of the failure to raise fuel taxes to keep pace with fuel economy and inflation has been the lack of sufficient revenue to invest in much-needed arterial, highway, and transit improvements. The shortfall in available revenues has also reduced the capacity of transportation agencies to pay for routine maintenance, leading to deterioration of the existing road network.

Faced with declining state and federal fuel-tax revenues relative to automotive travel, cities and counties have increasingly responded by raising additional local transportation revenue, often through sales taxes or general obligation bonds¹ (Goldman and Wachs, 2003). Voters

¹ Bonds to be repaid from general revenues.

in L.A. County, for example, have approved Propositions A (in 1980) and C (in 1990), two half-percent sales taxes dedicated to transportation projects. More recently, voters across the state approved approximately \$20 billion in general obligation bonds with Proposition 1B to fund a variety of transportation-improvement projects.

Yet such efforts have proven insufficient to offset the loss of state and federal fuel-tax revenues. Current projections indicate that the federal Highway Trust Fund (HTF)² will be depleted by fiscal year 2010–2011, while the California State Transportation Improvement Program (STIP)³ is already overdrawn. This is placing severe constraints on local transportation-improvement plans. Metro recently released its draft *2008 Long Range Transportation Plan*, providing a blueprint for transportation investments in the county through 2030 totaling approximately \$150 billion (Metro, 2008). This investment plan assumes the availability of certain federal and state revenues that, based on the current state of HTF and STIP, may not materialize. Moreover, the long-term transportation plan identifies numerous strategic projects that simply will not be possible unless additional revenue sources are developed. These include, among many others, the Metro Westside subway extension, the Metro Green Line extension to LAX, and carpool lanes for the 101 and the 10 (west of downtown Los Angeles) freeways, all of which have major implications for traffic conditions in Los Angeles.

Recognizing that many residents in the region would like to see these improvements implemented, local leaders have initiated discussions of possible strategies for raising additional transportation revenues at the regional level. Metro, for instance, has discussed the possibility of placing an additional 0.5-percent sales-tax measure for transportation funding on the ballot for voter approval in the fall of 2008. Assemblymember Mike Feuer, in turn, has introduced state legislation

² HTF receives revenues from federal motor-fuel excise taxes, which are then returned to states according to a federal distribution formula. Roughly 85 percent of the funding supports highway investments, while the remainder is allocated to transit and other alternative modes.

³ STIP, funded by state fuel excise taxes, provides revenue for roadway expansions and improvements. The State Highway Operation and Protection Program, also funded by state fuel-tax revenues, covers ongoing maintenance and operation costs separately.

(AB 2558) that would enable Metro to levy, again with voter approval, a local fuel tax of up to 3 percent of the purchase price (roughly \$0.12 to \$0.15 per gallon at current prices). Either of these options could help provide additional transportation funding for the region. As this assessment indicates, however, there are key advantages of the fuel-tax option in comparison with a sales-tax measure.

Evaluation of Strategy

Cost/Revenue Implications

Rating: High revenue. Preliminary estimates suggest that implementing a local fuel tax of 3 percent of the purchase price, as allowed for in Assemblymember Feuer's AB 2558 legislation, would result in annual revenue on the order of \$400 million to \$600 million per year ("Feuer Introduces Package of Transportation Bills to Raise Revenue for Local Projects," 2008).

Short-Term Effectiveness in Reducing Congestion

Rating: Low. Higher fuel taxes raise the cost of automotive travel, and this in turn provides an incentive for motorists to drive less. The Victoria Transportation Policy Institute, in reviewing a range of studies that examine how fuel prices influence travel behavior, concludes that the short-term elasticity⁴ of VMT with respect to changes in fuel prices is approximately -0.15 (VTPI, 2008e). What this means is that, if fuel prices rise by 10 percent, driving will decrease by 1.5 percent. In the case of AB 2558, the tax could be up to 3 percent of the purchase price, and this in turn would lead to about a half-percent reduction in overall travel. This would certainly not be enough to eliminate congestion, but it would help to a small degree.

⁴ *Elasticity*, a term favored by economists, measures the degree to which changes in the price of a good lead to changes in consumption patterns.

Long-Term Effectiveness in Reducing Congestion

Rating: Low. Over the shorter term, individuals are somewhat limited in the degree to which they can alter their driving behavior in response to changes in fuel prices. Over the longer term, however, if higher prices persist, they may choose to move, work closer to home, or alter other activity patterns so as to reduce the amount of driving (they may also choose to purchase more fuel-efficient vehicles, as we discuss later). As a result, fuel taxes can lead to even greater reductions in driving over the longer term. Again reviewing a range of studies from the literature, VTPI (2008e) concluded that the long-term elasticity of VMT with respect to fuel prices is closer to -0.30 . Thus, a 3-percent tax on the price of fuel would stimulate about a 1-percent reduction in driving over the longer term. Here again, the overall effects in reducing congestion can be characterized as *low*, but, in combination with other strategies, this strategy will be beneficial.

Mobility, Accessibility, and Traveler Choice

Rating: Good. Taxes on fuel, by leading to modest reductions in vehicle travel, will tend to reduce mobility to some extent. On the other hand, they will also help reduce congestion, and the revenues would likely be spent on a combination of road and transit improvements. This should help boost both accessibility and traveler choice. On balance, the advantages appear to outweigh the disadvantages, so we rate the strategy as *good* with respect to these other travel goals.

Safety

Rating: Good. Reducing vehicle travel should, in turn, reduce the total number of accidents (albeit to just a slight degree), resulting in a rating of *good* with respect to safety outcomes.

Economic Efficiency

Rating: Very good. There are two broad options for raising money to pay for transportation investments: general revenue sources and user fees. General revenue instruments—including income taxes, business taxes, property taxes, parcel taxes, sales taxes, and general obligation bonds—are not related to use of the transportation system, and their

revenues are often allocated across a range of social programs (hence the term *general revenues*). User fees, in contrast, are directly related to use of the transportation system, and the resulting revenues are more commonly (in the United States, at least) dedicated to transportation investments. Examples of user fees include licensing fees, vehicle-registration fees, fuel taxes, tolls, and parking fees.

In contrast to general revenue sources, user fees promote more-efficient use of the transportation system. As discussed in Chapter One, the marginal private costs of driving (including maintenance, gas, gas taxes, tolls, and parking fees) do not fully reflect the social costs imposed by driving (including road wear, congestion delays, and the emissions of air pollutants and greenhouse gases). As a result, individuals make numerous trips for which total costs exceed total benefits, and this reduces net social welfare (Downs, 2004). User fees help close the gap between the private and social costs of travel, thus encouraging individuals to forgo trips for which costs exceed benefits. This results in more-efficient use of the road network (Wachs, 2003b). In practical terms, user fees lead to reductions in congestion, emissions, and road wear. The reduction in vehicle trips, moreover, lessens the need for additional investments in road capacity. User fees are thus capable of raising revenue while simultaneously limiting the amount of additional revenue needed. General revenue sources, in contrast, fulfill the former goal but not the latter.

Note that the degree to which user fees promote greater efficiency depends on the specific structure of the fees. Here, it is useful to distinguish between fixed-cost and marginal-cost user fees. With fixed-cost user fees, users must periodically pay a fixed amount, but the amount paid is independent of the amount traveled. Examples include license and registration fees. Fixed-cost user fees can still influence travel behavior to some extent—for instance, higher registration fees may encourage some individuals to own fewer cars, and this, in turn, should lead to less total driving. With fixed-cost fees, however, once the fee has been paid, there is no additional motivation to drive less.

Marginal-cost user fees, in contrast, are tied directly to the amount one drives. Examples include fuel taxes, tolls, and parking charges. With such fees, each additional unit of travel increases the amount owed,

and this provides a strong and continuous incentive for drivers to forgo their least productive trips. Marginal-cost user fees—including fuel taxes—are thus more effective than fixed-cost fees, and far more effective than general revenue instruments, in stimulating more-efficient use of the road network.

Environment

Rating: Good. Over the longer term, increases in the price of gas lead to reductions in fuel consumption resulting from less VMT as well as the purchase of more fuel-efficient vehicles. As a result, the elasticity of fuel consumption with respect to changes in the price of gas is even higher than the elasticity of VMT. Based on a review of relevant studies from the transportation and economics literatures, VTPI (20078e) reported that estimates of the longer-term elasticity of fuel consumption with changes in price vary between -0.4 and -1.0 , with an average of about -0.7 . This means that a 3-percent tax on the price of fuel as allowed for in Assemblymember Feuer's proposed AB 2558 legislation could be expected to result in an overall reduction in fuel consumption of about 2 percent, helping to reduce greenhouse-gas emissions. The reduction in driving would also reduce emissions of local air pollutants.

Equity

Rating: Good. Equity is a function of the allocation of costs and benefits, and this can vary with different types of general revenue sources and user fees. Here, we compare fuel taxes with sales taxes, one of the most common alternatives for local transportation finance (Goldman and Wachs, 2003).

As a mechanism for raising revenue to pay for roads, fuel taxes promote greater equity by aligning costs and benefits (Wachs, 2003b). Sales taxes, in contrast, are unlinked to use of the road network, and, for this reason, those who drive less end up subsidizing those who drive more (all else equal), and those who do not drive at all must still fund

the roads for those who do.⁵ Given that wealthier individuals own more vehicles and travel more miles on average than those from lower-income groups (Pisarski, 2005), this raises equity concerns, especially among lower-income individuals who do not drive but still must pay for the roads. With fuel taxes, in contrast, the amount one pays is directly linked to the benefits one derives through use of the system. Those who drive more pay more, while those who drive less pay less.

It should be noted that *equity* can be defined in different ways (Taylor, 2004). While some view the alignment of costs and benefits as equitable, others would argue that the consideration of equity in transportation finance should be based on the ability to pay; that is, the cost burden should fall more heavily on wealthier individuals than on those from lower-income groups. Fuel taxes perform well with respect to the first of these definitions but not the second. Fuel taxes are *income regressive*—that is, though wealthier individuals typically pay more total fuel taxes than those from lower income brackets, poorer individuals must devote a greater share of their income to paying fuel taxes. On the other hand, sales taxes are also income regressive (Sorensen, 2006). In short, fuel taxes perform better than general revenue instruments when equity is defined in terms of aligning costs and benefits, while they are roughly comparable to sales taxes when equity is measured in terms of ability to pay.

A further wrinkle is added when a share of fuel-tax revenues is used to pay for transit improvements. This weakens, to some degree, the alignment of costs and benefits, in that drivers must subsidize transit service (although to the extent that such investments stimulate greater transit patronage and thus help to ease congestion, drivers may still benefit). That said, lower-income individuals are more likely to rely

⁵ Some may argue that those who do not drive still benefit from the transportation system whenever they purchase goods that have been transported across the road network, and this is clearly so. In a system in which user fees finance the roads, however, the user fees would constitute a portion of the cost of transporting goods, and such costs would be bundled into the ultimate purchase price of each item. Thus, those who do not drive would still pay their fair share of road maintenance and improvement costs indirectly, but they would not be required to subsidize the road network beyond that.

on transit than are higher-income individuals, so this arrangement may still be viewed as improving social equity.

To sum up, when considering ways to raise revenue for both road improvements and transit investments, fuel taxes make the most sense—in terms of both equity and economic efficiency—for the former. If sales taxes are to be included in the equation, a stronger argument can be made for using the revenue to subsidize transit than for relying on sales taxes to maintain and improve roads.

Stakeholder Concerns

Rating: Low. The two groups most likely to express concern about higher fuel taxes include automobile advocacy organizations and the trucking industry. Generally speaking, automobile advocates have been willing to support higher fuel taxes provided that the revenues are used primarily for road improvements. The trucking industry, in contrast, has often opposed higher fuel taxes in the past, as the purchase price of fuel has a direct impact on the profitability of trucking operations. In recent years, however, it has become increasingly apparent that current revenue sources are insufficient to either maintain or expand the road network as needed, and the subsequent growth in congestion has resulted in both wasted time and wasted fuel for truckers. Accordingly, the American Transportation Research Institute (2007), an organization funded by the American Trucking Association, recently released a study in favor of increasing fuel taxes to pay for better roads. Given this shift, stakeholder concerns are not expected to be significant.

General Political Obstacles

Rating: High/can partially mitigate—>medium. Opposition among the general public may be higher, especially given that gas prices are already at all-time highs and the economy is struggling. Yet increasing concern with the threat of global climate change may have altered the political calculus. Recent polling data for San Francisco Bay Area voters, for instance, suggest that an increasing percentage would support local fuel taxes provided that the revenues are dedicated to projects—such as transit investments—viewed as helping to reduce aggregate greenhouse-gas emissions (Gordon, 2007). Additional

research by Dill and Weinstein (2007) also suggests that voters in California respond positively to the idea of linking transportation fees with environmental goals. Thus, one of the challenges to local leaders is to highlight the links between fuel taxes and greenhouse-gas emissions—specifically, that higher fuel taxes encourage reductions in automotive travel as well as the purchase of more fuel-efficient vehicles.

Institutional Obstacles

Rating: Medium. The institution of local fuel-tax levies in L.A. County would require enabling state legislation.⁶ With Assembly-member Feuer’s proposed AB 2558 legislation, however, the prospects for state approval appear promising. Note that AB 2558, which is described as a *carbon-emission fee* to fund air-pollution and congestion-management programs, specifies that Metro could structure the fee either as a surcharge to the vehicle-license fee based on vehicle weight and emission class or as an additional tax on fuel of up to 3 percent of the purchase price (“Feuer Introduces Package of Transportation Bills to Raise Revenue for Local Projects,” 2008). As a variable-cost user fee, the fuel-tax option would have a stronger effect in reducing congestion than the vehicle registration–fee option.

To levy local fuel taxes in Los Angeles, then, the California legislature must pass AB 2558 (or an equivalent bill), and Metro must opt for the fuel-tax option rather than the registration-fee option. We interpret this as representing a *medium* level of institutional obstacles.

Current Status in the L.A. Region

Rating: Limited. Los Angeles does not currently levy local motor-fuel taxes. The county does, however, have two half-percent sales-tax measures to raise transportation revenue (Propositions A and C), and they apply to purchases of fuel as well as other goods. In combination, these result in a 1-percent local sales tax on fuel, resulting in about

⁶ California legislation (AB 595, enacted on October 11, 1997) allows the Metropolitan Transportation Commission, subject to voter approval, to levy a regional fuel tax of up to \$0.10 per gallon for nine counties in the San Francisco Bay Area, though to date such a tax has not been implemented. No other areas in the state are currently granted the right to enact local fuel taxes.

\$0.03 to \$0.04 per gallon at current prices. We thus rate the current status of local fuel taxes in Los Angeles as *limited*, even though the county does not yet levy taxes that apply just to fuel.

Interaction with Other Strategies

Fuel taxes make driving more expensive and thus complement or reinforce other strategies that seek to either reduce automotive demand directly or improve the relative attractiveness of alternative modes. Examples include ride-sharing (see Appendix B11), telecommuting (see Appendix B12), cordon congestion tolls (see Appendix B19), variable curb-parking rates (see Appendix B20), employer parking cash-out (see Appendix B21), deep-discount transit-fare passes (see Appendix B24), BRT (see Appendix B25), pedestrian improvements (see Appendix B27), and bicycle improvements (see Appendix B28). Local fuel taxes will also raise considerable revenue that could help fund many of the strategies considered in this document.

Variable Transit Fares

With a variable transit-fare structure, the fare paid depends on one or more factors of a rider's journey. There are many kinds of variable fare structures currently in use. Common options include a time-based structure, in which riders pay more to use transit during peak travel periods; distance-based fares, in which the price increases with the distance traveled; and zone-based fares, which increase as a rider enters and exits demarcated zones, rings, or cordons around an area. Other variable fare structures include direction-based pricing (in which the charge increases for trips in the peak period and peak direction of flow) and mode-based fares (which differentiate between alternative transit modes, such as local buses, express buses, and light and heavy rail services). These alternative variable fare structures can be used individually or in combination. Variable fare structures are currently more prevalent for rail transit systems, but they can be (and, in some cases, are) used with bus services as well.

The principal rationale for implementing variable fare structures is to better align the fare that a transit rider pays with the marginal cost of providing the transit ride. To illustrate, consider the idea of time-based pricing for bus services. Typically, the level of ridership during peak hours drives the number of buses in a transit operator's fleet. As more peak-hour riders are added, therefore, it soon becomes necessary to buy more buses and hire more drivers. The marginal cost of providing each peak-hour trip is therefore high, and this would be reflected in higher fares during the peak hours. In contrast, ridership may be much lower in the middle of the day, so the bus system remains underuti-

lized during this period. It is thus possible to add many new riders in the middle of the day without needing to buy more buses or hire more drivers, so the marginal cost of providing each additional ride is quite low during this time. This would be reflected in lower fares during the off-peak hours. Similar arguments can be made for distance-based fares and mode-based fares (rail, unless heavily patronized, often costs significantly more per trip than bus service; Litman, 2004).

By aligning fares with marginal costs, transit operators can maximize their fare-box recovery as a percentage of capital and operating costs. This, in turn, should allow them greater latitude in investing in service improvements. Research indicates that ridership elasticity with respect to various aspects of service quality is higher than it is for price. By optimizing fare-box recovery and allocating the additional funds to provide better service, transit operators should thus be able to increase total ridership even with higher fares for longer trips or trips during peak periods (Litman, 2004).

Despite the advantages of variable fares, most transit providers in the United States use a flat fare structure to collect passenger revenues, though the percentage of providers that implement some form of variable pricing is higher in larger metropolitan areas. The Washington Metropolitan Area Transit Authority (WMATA) rail system is one well-known example of the application of variable fares. On WMATA's rail system, the price that passengers pay to use the system varies by the distance they travel (as measured by the number of zones through which they pass) and whether the trip falls during rush hour. San Francisco's BART also implements variable fare pricing on its rail system, one that differentiates fares based on the distance a user travels.

Evaluation of Strategy

Cost/Revenue Implications

Rating: Low revenue (uncertain). It is difficult to predict the specific effects of a variable fare structure on costs and revenues because they will depend on a range of factors. How much will some fares be lowered? How much will other fares be raised? How responsive is rid-

ership to changes in fare levels, and how does this vary across different types of trips (e.g., for short, discretionary, off-peak transit trips versus longer, peak-hour commuting trips)? Will the transit provider use any additional revenues to improve service, and will this, in turn, generate additional riders and additional fares? It is possible to answer such questions through focused survey research and other methodologies, but doing so was beyond the scope of this study.

In general, variable fare structures, if well designed, should improve the ratio of fare-box recovery to capital and operating costs—perhaps by a small amount, or perhaps by a large amount. On the other hand, some costs may also be associated with installing the equipment or hiring additional staff to help implement variable fares. Taking all of these factors into consideration, we have opted for the relatively conservative rating of *low revenue* for variable fare structures, though we describe this rating as *uncertain*.

Short-Term Effectiveness in Reducing Congestion

Rating: Negligible. It is unlikely that implementing variable fare pricing would have much effect on congestion in the short term. The most dramatic gains in ridership would occur over shorter distances during off-peak times, when fares would be lower. In contrast, fares would likely increase for longer trips during peak hours, which could have the effect (at least in the short run) of dampening transit demand. This would certainly not reduce traffic congestion, and it could, in fact, even lead to slight increases in congestion.

Long-Term Effectiveness in Reducing Congestion

Rating: Low (uncertain). Over the longer term, the institution of variable transit-fare structures could facilitate modest reductions in congestion. For this to occur, transit operators would need to devote any increase in fare-box revenues to fund additional service improvements. This could help attract additional riders—even with higher prices at the peak—which, in turn, could help relieve congestion. That said, triple convergence would ultimately limit the extent of traffic reductions. If improved transit service leads to significant traffic reductions, drivers will likely converge on the newly freed road capacity—from

other modes, other routes, or other times of day—thereby eroding a substantial proportion of the gains. As such, we rank the long-term effectiveness of variable fare structures in reducing traffic congestion as *low*. Because even this modest improvement rests on transit operators' willingness and ability to invest additional fare revenues in improving service, we also characterize this rating as *uncertain*.

Mobility, Accessibility, and Traveler Choice

Rating: Good. Variable fare pricing will increase the cost of using transit during peak periods and over longer distances and therefore may slightly reduce the number of such trips. On the other hand, it will reduce the cost for shorter, off-peak trips, thus yielding increased ridership for trips that are less expensive to provide. In addition, if increased fare-box recovery revenues are used to enhance service quality, even more new transit trips may be stimulated. As more drivers opt to use transit, additional road space will be freed for other automotive trips. The phenomenon of triple convergence may prevent significant lasting reductions in congestion, but aggregate social mobility across multiple modes will still be increased. On balance, then, it should be expected that variable fare structures would offer positive benefits in terms of mobility, accessibility, and traveler choice.

Safety

Rating: Neutral. It is not expected that variable transit fares would have a significant effect—either positive or negative—on safety outcomes.

Economic Efficiency

Rating: Very good. By aligning fares with the marginal cost of providing additional trips—on different transit modes, over different distances, or at different times of day—variable fare structures support a much greater degree of economic efficiency in transit services. Specifically, they encourage higher ridership for trips that can be offered for little or no additional marginal cost while charging more for the trips that are most expensive to provide at the margin. The net effect is to increase fare-box-recovery rates as a percentage of capital and operat-

ing costs. Viewed from a different perspective, variable fare structures enable transit providers to maximize the number of trips served for a given level of subsidy.

Environment

Rating: Neutral. Over time, as argued, variable fare structures are likely to lead to a net increase in transit patronage. However, many of the additional trips served may not replace traveling by car. For example, with cheaper fares over shorter distances in the off-peak hours, some passengers may choose to make short transit trips instead of walking. Even for new trips that replace auto journeys, the effects of triple convergence will slowly but surely offset the benefits. For these reasons, the net environmental effects are likely to be negligible.

Equity

Rating: Very good. A variable fare structure can offer significant improvements in equity (Cervero, 1980, 1981). Flat fares are based on an average systemwide price for all trips, regardless of how much it costs to provide each trip. As a result, those who use buses, travel shorter distances, or travel at off-peak times end up cross-subsidizing those who use rail, travel longer distances, or travel during peak hours. Evidence suggests that those who depend on transit—including relatively large proportions of poor, female, nonwhite, teenaged, and elderly populations—are much more likely to use bus service over short distances during off-peak hours. As a result, flat fare structures create a situation in which these traditionally disadvantaged groups help underwrite the costlier transit trips of long-distance peak-hour commuters who, as a group, are more likely to be male, white, and more affluent. The adoption of variable fare structures represents an effective means of redressing this imbalance (Luhrsen and Taylor, 2003).

Stakeholder Concerns

Rating: Low. Concerns could arise among riders whose fares would increase under a variable fare structure—specifically, those who use rail, who travel longer distances, and who travel in the peak hours. As a group, however, long-distance transit commuters tend to be more

affluent and thus more able to afford higher transit fares. In addition, if the increased fares are reinvested in transit-system improvements that these customers value, resistance to the fare increases may be further reduced. In general, then, the level of stakeholder concerns should be relatively muted.

General Political Obstacles

Rating: Medium/difficult to address—>medium. The general political obstacles associated with implementing variable fare pricing on transit are not likely to be high. That said, elected officials representing suburban areas with a large proportion of long-distance transit commuters may object that the burden of variable fares falls disproportionately on their constituents.

Institutional Obstacles

Rating: Medium/can partially address—>low. Implementing variable fare structures would require a significant shift on the part of transit providers in terms of how they collect fares. For example, it would become necessary to track where passengers boarded, where they alighted, and the time of their travel. Implementing such a dramatic technology shift can be challenging for larger bureaucracies, such as Metro. On a positive note, however, numerous transit operators both in the United States and abroad have already successfully implemented variable fare structures, and there is a range of technical options from which to choose. One promising strategy is the use of smart cards, as discussed later.

Current Status in the L.A. Region

Rating: Limited. There are currently very few applications of variable fare structures in the L.A. region. Metro, by far the largest transit provider in the region, uses a flat fare structure for the vast majority of its lines. (There are a few zone-based fares on the Harbor Transitway, the El Monte Busway, and several other freeway bus lines, but these are exceptions rather than the rule.)

Metro has considered wider adoption of variable fare structures in recent years but thus far has not chosen to pursue that path. In 1999,

the agency commissioned a study to examine alternative fare structures and pricing strategies, including the implementation of zone-based prices on rail and discounts for off-peak bus travel. While the study suggested that the zone-based pricing for rail should be given further consideration, it did not recommend off-peak pricing for buses. Even though the “introduction of a mid-day discount would likely produce a marginal increase in overall daily ridership, the loss of fare revenue and the added complexities it would introduce, including potential rider-driver confrontations, argue against it” (de la Loza, 1999, p. 23). Neither of the recommendations resulted in any fare-policy changes. One of the main reasons cited for not implementing the changes was Metro’s belief in the importance of keeping fare structures simple.

More recently, the Metro’s board of directors approved funding for a study of retrofitting the rail system to be able to handle distance- and time-based fare structures. The study results are expected to be available in late 2008. Among the areas that the study plans to address is the cost-effectiveness of such a policy. Retrofitting the rail system would require capital improvements to every entrance in it. Additionally, there would be labor costs associated with monitoring the turnstiles. Variable fare structures for the bus system are not currently under consideration.

Although Metro (along with other transit providers in the region) has yet to fully embrace variable fare structures, it is currently funding and leading the development of a smart-card system known as the Los Angeles transit-access pass (LA TAP) that will work across different transit providers in Los Angeles. Successful implementation of the TAP system will make it much easier to implement variable fares later should that decision be made.

Interaction with Other Strategies

One of the aims of variable transit fares is to raise additional revenue by charging more for the trips that cost the most to provide—namely, longer trips and peak-hour trips. The additional revenue can help fund transit-service improvements (see Appendix B25 and B26). Variable transit fares also encourage increased ridership for shorter and off-peak trips; this promotes greater mobility and traveler choice, though it has

less impact on congestion. Note that variable transit fares do not mesh well with deep-discount fare programs (see Appendix B24), which allow participants to travel as much as they want for one monthly fare.

Deep-Discount Transit Passes

Deep discounting is the term commonly used to describe programs in which a transit agency sells unlimited-access transit passes at significantly reduced prices for all members of a large organization. Deep-discount transit passes might be offered, for example, for

- all employees of a large corporation
- all employees of a government agency
- all students, staff, and faculty at a university.

To qualify for the significant price reduction, the organization is typically required to purchase passes for all of its members. Individual members will then be provided with the pass as a benefit free of charge (that is, the employer or organization bears the cost of the passes).

Deep-discounting programs, if well designed, can benefit all parties involved (Nuworsoo, 2004): the sponsoring organization, its members, the transit agency, and society at large. If the sponsoring organization is an employer, for example, providing free transit passes to employees may be seen as a valuable benefit to attract and retain employees, and it may reduce the number of parking spaces that the employer needs to lease (assuming that it does not own its own parking facilities). In addition, as more employees switch to transit, the program may serve as a cost-effective method for helping the employer meet any applicable automotive trip-reduction goals. If the sponsoring agency is a university, the provision of free transit passes may serve a valuable form of financial aid that effectively lowers students' transpor-

tation costs. It may also ease the need to construct new parking facilities as the university expands over time.

For members or employees of the sponsoring organization, the availability of free transit passes can significantly reduce commuting costs. Those members who use transit will no longer have to purchase individual fares or monthly passes. Those who switch from driving to transit may be able to forgo auto ownership entirely, or at least save some percentage of the money normally spent on gas and parking fees.

The transit provider, in turn, stands to increase ridership, increase revenues per rider, and decrease the average cost of service per rider (i.e., reduce the per-rider operating deficit) by offering deep-discount fare programs. Ridership goes up because the sponsoring organization, rather than its members, pays for their transit use. Revenues per rider will increase provided that the total annual cost of purchasing passes for all members of the organization divided by the number of members who choose to use the pass exceeds the average annual fares paid by members who had used transit before the deep-discount program was initiated (in practice, this means that some care must be devoted in selecting the appropriate price to charge for the discounted passes; see Nuworsoo, 2005). Finally, deep-discount programs can target organizations whose members travel more frequently at off-peak times (e.g., students) or who are located along underutilized transit routes. This reduces the marginal cost of serving each new rider, which, in turn, can lower the average systemwide per-rider cost.

To the extent that deep-discount programs can improve transit revenues and reduce average per-rider costs, they can also help reduce the level of public subsidization required to support transit services. By increasing ridership, deep-discount programs will also help reduce automotive travel, thereby easing congestion to some extent.

Evaluation of Strategy

Cost/Revenue Implications

Rating: Low, medium revenue. As argued in the preceding section, deep-discounting programs offer the potential for increased tran-

sit ridership, increased revenue, and lower operating deficits. Research on existing programs supports this proposition (Nuworsoo, 2004). For example, case-study analyses have found that deeply discounting passes produces up to three times the per-boarding revenue that the systemwide average is without deep discounting. As a result, the “deep discount group pass may be an instrument for increasing operating revenues and hence system efficiency. Everything else being equal, the more revenue that is raised, the less society might need to subsidize operations” (Nuworsoo, 2004, p. 1).

Short-Term Effectiveness in Reducing Congestion

Rating: Low. In the short term, deep-discount programs may have a modest effect on traffic reduction by increasing the number of commuters who choose to use transit rather than drive. Brown, Hess, and Shoup (2001), for instance, reported that implementing deep-discount fare programs has resulted in transit-ridership gains of between 70 and 200 percent among the members and employees of participating organizations and firms. The net reduction in traffic congestion may be somewhat limited, however, since these programs are often instituted by organizations—such as universities—whose members are more likely to travel during off-peak periods, when congestion is less of a concern.

Long-Term Effectiveness in Reducing Congestion

Rating: Low. Over the longer term, even if deep-discount programs stimulate an increase in the number of transit users, triple convergence is likely to offset any traffic-related benefits, as latent and induced demand combine to reclaim any freed road capacity.

Mobility, Accessibility, and Traveler Choice

Rating: Very good. The direct effect of deep-discount passes is to make transit essentially free for members of a sponsoring organization that purchases the passes, which clearly enhances their mobility, accessibility, and traveler choice. Indirectly, by helping to improve revenues and reduce operating deficits, deep-discount programs may allow

transit providers to invest in even higher-quality service. This can help improve the mobility and accessibility of other riders as well.

Safety

Rating: Neutral. To the (likely limited) extent that deep-discount fare programs reduce automotive travel and relieve congestion, there may be some decrease in the number of vehicle accidents. On the other hand, the number of pedestrian trips—which also carry significant safety risks—may increase as more people walk to and from transit stops. Overall, however, the net safety effects are expected to be negligible.

Economic Efficiency

Rating: Good. As noted, deep-discount programs are often targeted toward organizations whose members are more likely to patronize underutilized routes or travel at off-peak times. This can lead to more-efficient use of existing transit capacity, thereby supporting the goal of economic efficiency (Nuworsoo, 2004).

Environment

Rating: Neutral. Though deep-discount programs may lead to an initial shift from the automobile to transit, triple convergence will tend to offset these gains to some extent over time. The environmental benefits—though positive—are therefore likely to be negligible.

Equity

Rating: Good. It is not clear whether the direct benefits of deep-discount programs—that is, the availability of free transit passes for members of sponsoring organizations that have purchased the passes at a discount—will disproportionately benefit lower- or higher-income groups. That said, the members who choose to take advantage of the free transit pass (e.g., students, who earn little, if any, money) are more likely to occupy the lower end of the income spectrum. In addition, if deep-discount programs can reduce operating deficits and thereby free additional funds for further transit improvements, all other system patrons will benefit as well. Given that the individuals who most rely

on transit are more likely to be poor or otherwise disadvantaged (Pisarski, 2006), this certainly promotes improved equity outcomes.

Stakeholder Concerns

Rating: Low. Provided that organizations, such as universities or large employers, are not required to enroll in the deep-discount program but rather have the option to do so if they wish, stakeholder concerns should be negligible. It is possible that advocates for lower-income transit riders who do not belong to an organization that provides such passes free of charge to its members could choose to view the arrangement as being unfair to their constituents. On the other hand, because deep-discount programs can promote greater fiscal solvency among transit providers—which, in turn, lessens the pressure to raise general fares or cut service—such critiques are less likely to materialize.

General Political Obstacles

Rating: Low. The political obstacles associated with deep-discount programs should be minimal.

Institutional Obstacles

Rating: Medium/can partially address—>low. One institutional challenge associated with deep-discount programs is determining an appropriate per-member price for the passes so that they benefit transit agencies and sponsoring organizations alike. If the passes are intended to work on multiple transit systems—a feature that would be very useful in many parts of Los Angeles—it is also necessary to figure out an appropriate division of deep-discount fare revenues among those transit providers. These challenges can certainly be overcome, but careful analysis and negotiations will be required.

Current Status in the L.A. Region

Rating: Moderate. Metro already provides deep-discount transit passes for some employers and institutions, though the specifics of the fare structure vary from one organization to the next. As part of a trial implementation of the new TAP smart-card system being developed by Metro and other transit agencies in the region, many of the exist-

ing deep-discount programs are currently using the TAP cards. When the TAP system is fully implemented, the deep-discount passes should provide transit access across multiple transit operators, making the programs even more effective.

Interaction with Other Strategies

Deep-discount programs may complement other employer-based efforts to reduce automotive commuting, such as mandatory TDM programs (see Appendix B16) and employer parking cash-out (see Appendix B21). Because deep-discount programs can provide additional transit revenue with little marginal cost, they can also generate some of the funds needed to invest in other transit system-quality improvements (see Appendixes B25 and B26). Finally, they may complement strategies that raise the cost of driving—such as cordon tolls (see Appendix B19), variable curb-parking rates (see Appendix B20), and local fuel taxes (see Appendix B22)—by making transit even more attractive in comparison.

Bus Rapid Transit

BRT refers to a set of strategies intended to boost the performance, capacity, convenience, safety, and cost-effectiveness of bus transit. Common strategies include the use of grade-separated busways or bus-only lanes, high-frequency service, simple route structures with limited stops, advance fare-payment systems, and the use of ITS to provide traffic-signal preemption or priority and traveler information. Specific BRT features may involve improvements to vehicles, to the operating structure, to the routes or right-of-ways, to the stations, or to the ITS technology platform. Table B25.1 provides a list of common BRT features, along with the outcomes they are intended to improve.

While many of the column titles in the table are self-explanatory, several merit additional comment. First, overall travel time via the bus system includes such components as passenger wait times and transfer times, en-route vehicle travel times, and station dwell times (the time that a bus takes to stop at a station to pick up and drop off passengers); the “Travel or Dwell Time” column indicates whether various BRT features will improve one or more of these components. The “Physical Accessibility” column indicates BRT features that will help make bus transit more accessible to all segments of society, including those with physical disabilities (for instance, automated next-stop announcements make it easier for visually impaired individuals to navigate the bus system). Finally, the “Congestion” and “Emissions” columns indicate BRT features that help reduce the degree to which buses themselves contribute to congestion and emissions. BRT systems as a whole can, of course, provide additional benefits related to congestion and emissions

Table B25.1—Continued

Improvement	Travel or Dwell Time	Service Reliability	Capacity	Physical Accessibility	Traveler Info.	Comfort, Safety	Image, Identity	Congestion	Emissions
Headway-based scheduling	•	•							
Frequent service	•	•	•	•		•			
Route or right-of-way									
Bus-stop turnouts	•							•	
Queue-jump lanes at intersections	•	•							
Bus-only lanes on arterial system	•	•							
Bus use of freeway HOV or HOT lanes	•	•							
Grade-separated bus-only lanes	•	•						•	
Mechanical or optical guidance systems	•	•		•					
Station									
Off-vehicle fare payment	•								

by encouraging more travelers to switch from driving to transit; this latter category of improvements is discussed in a later section.

BRT features can be implemented individually or as packaged features that work in concert. BRT systems in the United States and around the world vary significantly in terms of feature implementation and resulting performance gains, ranging from modest bus-service improvements on one end of the spectrum to rail-like performance and reliability on the other. Similarly, the costs of BRT systems also vary, depending on technology features employed and whether land is acquired to create dedicated busways (Hess, Taylor, and Yoh, 2005). In any case, it is clear that many transit officials and planners hope to use some combination of BRT features as a relatively low-cost strategy to improve service for existing riders and to attract new riders.

Because of the wide range of available strategies, BRT offers some advantages over other forms of rapid transit (e.g., subways or light rail). First, BRT offers flexible routing options. Because buses rely on rubber tires rather than rail, BRT service can use existing, mixed-flow traffic lanes, including both arterials and freeways. BRT can also operate on dedicated, grade-separated busways or HOV lanes on the freeway system. Capitalizing on this flexibility, BRT service can operate, for example, on a grade-separated busway for the line-haul portion of a trip, then deviate onto local arterials to serve stops or activity centers that are not directly connected to the transitway. In other words, BRT can provide both trunk and feeder services. And as travel patterns change over time, BRT can be rerouted as needed to serve new markets.

Second, the staging of BRT implementation is flexible and can be phased in over time as travel demand grows. Certain features of BRT are relatively easy to implement in the short term because they do not require capital-intensive installations like the fixed tracks, electric-power supplies, or signal systems required in rail development. At the same time, BRT offers potential for longer-term transition to higher-capacity service (e.g., adding dedicated busways or transitioning to rail) as ridership increases. This enables stepwise, incremental implementation: Lower-cost investments can be instituted first, while the more expensive and sophisticated elements of BRT can be added over time as demand grows and funding becomes available. BRT can also be used

to test promising markets for higher levels of service without the need for significant up-front investments. BRT does not compromise future needs for higher-capacity modes, as rail-like stations and rights of way can be developed and later converted to rail service.

Third, less expensive BRT features can be used for cost-effective improvements to regular bus service. Many BRT treatments—such as low-floor buses, simple route structures, frequent service, stations on the far side of intersections, electronic payment systems, and signal prioritization—need not be limited to specific BRT routes but can instead be implemented systemwide to improve all bus service.

The concept of BRT is not new. Plans for bus systems with BRT-like features have been in existence since the 1930s in such cities as Chicago, Washington, D.C., St. Louis, and Milwaukee (Levinson, Zimmerman, Clinger, and Rutherford, 2002). BRT has, however, gained interest and popularity in recent years. This is due, at least in part, to the demonstrated success and cost-effectiveness of advanced BRT systems in such cities as Curitiba, Brazil, and Bogotá, Columbia. Another compelling factor is that BRT tends to cost less and offer greater flexibility—in terms of both routing and phased implementation—than fixed light- or heavy-rail systems. As a result, BRT systems are now found in many cities around the world as well as in the United States, including Boston, Chicago, Cleveland, Denver, Honolulu, Los Angeles, Miami, Oakland, Orlando, Philadelphia, Phoenix, Pittsburgh, San Jose, and Seattle (Levinson, Zimmerman, Clinger, Rutherford, et al., 2003).

In Los Angeles, Metro has been operating BRT services since June 2000. The BRT system, referred to as Metro Rapid, began with two pilot lines incorporating such features as simple route structures, limited stops, frequent headway-based scheduling, signal prioritization, clean-fuel vehicles, next-bus-information signs, and distinctive vehicle and bus-stop design. In response to these innovations, ridership on Metro Rapid increased considerably, especially along the Wilshire corridor. Since its introduction, the Metro Rapid program has been expanded to 18 lines in current operation, and it is expected to serve 26 corridors spanning 450 route-miles in the near future.

BRT in Los Angeles also includes the Metro Orange Line, which opened in 2005. The Orange Line, which provides rail-like bus service along a 14-mile exclusive transitway in the San Fernando Valley, includes 60-foot vehicles with multiple entry doors, automated station-announcement systems, and next-bus signs at each station.

Evaluation of Strategy

Note that most of the individual BRT features listed in Table B25.1 could conceivably be planned and implemented within a five-year period and thus qualify as near-term options in the context of this study. One exception, however, is the development of grade-separated bus-only transitways, which would require a much longer time frame. For this reason, our evaluation of BRT strategies does not include the option of building new grade-separated bus-only lanes but focuses on the remaining features instead.

Cost/Revenue Implications

Rating: Medium cost (uncertain). The cost of implementing BRT varies considerably based on the specific set of features selected for adoption. Grade-separated busways, though not a short-term measure, can be very expensive. Even some of the shorter-term options, however, such as upgrades to the existing bus fleet, elaborate bus-station structures, or electronic fare-payment systems, may require significant capital outlays. Other options, such as signal prioritization and next-bus traveler-information signs, rely on sophisticated ITS technology, and this can be costly to install if the required ITS infrastructure has not already been developed as part of a region's transportation system.¹ Other BRT features suitable for implementation in the short term, however, are likely to be less capital-intensive. Examples of moderate-

¹ Note that, in the case of Los Angeles, signal synchronization and control through LADOT's ATSAC center were already developed for traffic management, with costs borne by nontransit agencies. ATSAC's application and extension to BRT required little additional outlay. For a discussion about variability in accounting practices that can influence operating and capital cost comparisons, see Hess, Taylor, and Yoh (2005).

or low-cost improvements include restriping and resigning streets for bus-only lanes, widening the streets over short segments to provide bus queue-jump lanes at congested intersections, outfitting local buses with transponders to allow bus priority at traffic lights, skip-stop service, headway-based scheduling, and higher-frequency service. Though more-frequent service can increase operating costs, these costs can be mitigated through reductions in service on underused or duplicative lines (for more on this idea, see discussion of the bus route–reconfiguration strategy in Appendix B26).

The revenue implications of BRT strategies depend on the level of ridership increases resulting from the improvements. Increased ridership should lead to more fare-box revenue and increased allocation of formula-based regional transit subsidies, which can help offset, to some extent, the investment in BRT improvements. Given that many BRT improvements are relatively costly and that there may also be some revenue gains, we rank the net cost/revenue implications as *medium cost*. We also describe this ranking as *uncertain*, however, in that the specific cost and revenue outcomes depend on the specific set of features adopted as well as the bus routes selected to receive the improvements.

Short-Term Effectiveness in Reducing Congestion

Rating: Low. As demonstrated in Los Angeles and elsewhere, BRT systems can lead to significant gains in transit use. Metro’s Wilshire Rapid line, for example, resulted in considerable increases in new ridership shortly after its introduction in 2000, while the Orange Line has far exceeded its initial ridership projections. Such gains certainly help reduce traffic flow to some extent. Yet transit use represents such a low share of overall travel that even significant percentage gains in transit ridership translate to relatively low-percentage reductions in auto traffic. For this reason, BRT is ranked as *low* in terms of short-term congestion-reduction potential.

Note that, if BRT could produce significant travel-time savings relative to the automobile, it would be possible to overcome some of the primary advantages of the automobile, such as greater flexibility and convenience, and induce even more travelers to use transit rather than drive. To achieve such travel-time savings, however, it would

likely be necessary to either develop a network of grade-separated busways or convert numerous general-purpose arterial and freeway lanes to bus-only lanes or shared bus and carpool lanes. The former option is beyond the short-term time scope of this study; the latter, while possible in the short term, would reduce the capacity available for SOVs and thus could conceivably make congestion worse in the remaining general-purpose lanes if not enough motorists shifted to transit.

Long-Term Effectiveness in Reducing Congestion

Rating: Low. Over time, as BRT systems become better developed and better known, ridership may continue to increase. Unless complementary policies that internalize the full costs of driving (such as parking fees, congestion tolls, or VMT fees, for example) are put into place, however, the effects of triple convergence can be expected to undermine any long-term congestion reduction from improved transit operations through BRT development.

Mobility, Accessibility, and Traveler Choice

Rating: Very good. The addition or expansion of BRT service can provide direct travel benefits in the form of increased mobility, accessibility, and expanded travel options for those who cannot drive or who prefer alternative transportation choices. These benefits apply to existing riders as well as new riders.

Safety

Rating: Bad/can be partially mitigated—>neutral. Given that BRT services typically rely on vehicles and road infrastructure similar to those of normal bus services, one would expect safety-related outcomes to be neutral. There are, however, several issues of potential concern. First, if curbside bus-only lanes are developed in high-density corridors, there may be some safety risks in pedestrian-oriented areas. This can be mitigated, however, through sidewalk landscaping to provide physical separation between pedestrian and bus traffic. Second, if dedicated busways are not fully grade-separated, there may be a higher risk of collisions with automobiles at intersections, especially when the busways are first opened and auto drivers are not yet aware of the risk.

This occurred, for instance, with the recent development of the Orange Line. The danger can be mitigated, at least to some extent, by providing very clear signage and warnings, as well as by aggressively enforcing crossing violations to deter unsafe behavior near the intersections.

Economic Efficiency

Rating: Good. BRT serves the goal of economic efficiency in several ways. First, it increases the quality of transit services, helping to induce a more efficient modal split. Second, BRT enables a transit operator to serve more passengers for a given level of investment, further improving economic efficiency. Third, BRT allows for flexible phasing of improvements, such that operators can invest in lower-cost options to begin with, then pursue higher-cost improvements as warranted by increasing ridership. This limits the risk, at each stage, that the improvements will be underutilized.

Environment

Rating: Good. BRT can produce environmental benefits through several mechanisms. First, if BRT can shift motorists out of their cars to fill existing capacity on transit vehicles, there should be a net reduction in per-traveler emissions generated by the transport sector. Second, the use of high-capacity vehicles in high-demand corridors will raise average bus occupancy rates, thereby reducing emissions per transit rider. Third, any overall decrease in traffic, even if limited, will reduce congestion delay and bus dwell times, thereby reducing emissions from bus and automobile idling.

Equity

Rating: Very good. BRT provides direct travel benefits to existing riders, and this group is characterized by larger percentages of low-income and racial and ethnic minority travelers, as well as those who cannot or choose not to drive. BRT not only provides more travel choices to riders, but also provides higher-quality service, reduced travel times, and increased reliability. At the same time, the implementation of certain BRT features can provide benefits to riders of local (non-BRT) lines. For example, bus-only lanes or enhanced stations

developed for BRT projects can also benefit local buses that can use the same lanes and stations. Low-cost transponders installed on BRT vehicles to allow signal priority can also be installed on local buses to improve travel times.

Stakeholder Concerns

Rating: High/can partially address—>medium. Many BRT features produce benefits for transit riders without creating negative consequences for other motorists or surrounding communities and thus are unlikely to engender stakeholder opposition. Examples in this category include skip-stop service, low-floor buses, faster payment systems, and next-bus information systems. In contrast, stakeholder opposition is likely to be high where the implementation of BRT services imposes costs (real or perceived) on other drivers or on local residential or business communities. One of the most potent BRT strategies for improving bus travel times along the arterial system—the creation of bus-only lanes—falls squarely into this category. If a general-purpose travel lane is converted to bus-only (or bus and carpool) operation, and if this transition fails to produce a significant mode-shift from auto to transit, congestion in the remaining general-purpose lanes may very well worsen. Such a shift could therefore be expected to raise significant objections from motorist advocacy groups. Such objections could diminish over time if motorists perceive that bus-only lanes carry more people than general-purpose lanes do (Levinson, Zimmerman, Clinger, Gast, et al., 2003).

Local business leaders may also oppose the removal of curbside parking for bus-only lanes on the arterial system. To address this concern, Los Angeles has implemented demonstration projects with bus-only lanes enforced during peak periods, when curbside parking is already prohibited. Businesses are also less likely to oppose bus-only lanes if they are implemented regionally, as opposed to being implemented in just a few areas. Regionwide implementation reduces the risk that local business groups will feel like they have been unfairly targeted or that they will be unable to compete with businesses elsewhere. Over the longer term, if the addition of bus-only lanes stimulates significant transit-ridership gains and thereby expands the number of passenger

trips in a corridor, the local economy likewise stands to benefit, helping to offset any initial concern about parking losses (Streeter, 2003).

General Political Obstacles

Rating: Medium/can fully address—>low. Beyond the potential stakeholder concerns outlined in the preceding section, BRT is unlikely to generate additional political opposition. One factor that should be noted, however, is the historical proclivity of elected officials to favor higher-profile (and higher-cost) investments in light and heavy rail over bus-system investments. Recent trends suggest, however, that this preference may be shifting. To begin with, both the Metro Rapid program and the Orange Line have been enormously successful, leading to significant ridership gains for a much lower level of expenditure than would be required for rail. Second, the gradual decline in the availability of federal and state transportation dollars has made it less feasible to pursue costly rail investments, and, as a result, BRT represents a more realistic option for many corridors. These trends are helping to reduce political opposition to BRT investment.

Institutional Obstacles

Rating: High/can partially mitigate—>medium. For BRT treatments that fall within a transit agency's direct control, institutional obstacles are likely to be quite low. Some of the most compelling features, however, such as dedicated bus lanes or signal prioritization, will require coordinated efforts with multiple jurisdictions and agencies. In addition, while transit operators construct and provide bus-stop shelters, stations, and signposts, the sidewalks on which they must be placed fall under municipal control.

Bus-only lanes may present conflicts with curbside metered parking—a valuable source of local revenue over which municipalities may be unwilling to cede control. At the same time, bus-only lanes may conflict with commercial loading zones, passenger-loading zones, and taxi zones, and overcoming these conflicts will require coordination as well. Finally, the curb-lane repairs necessary for faster bus operations may require assistance from public-works departments.

Implementation of the signal-priority system likewise requires significant institutional coordination in which transit agencies must work closely with city and county DOTs to develop signal-timing strategies that minimize delays for buses while avoiding significant adverse effects on general traffic. The potential for institutional obstacles can be reduced by introducing BRT improvements in multiple phases and by fine-tuning and evaluating the program before adding rapid lines. For example, the Metro Rapid pilot program demonstrated increased ridership with minimal effects on cross-street traffic (Metro, 2000) before the next phase of Metro Rapid service expansion was implemented.

Current Status in the L.A. Region

Rating: Moderate. While the L.A. region is much further along in implementing BRT features than many other metropolitan areas, to date, there has been only limited development of bus-only lanes or grade-separated transitways. For this reason, we rate the current status as *moderate* rather than *significant* or *advanced*.

Metro first began its Rapid program in 2000 with demonstration lines along the Wilshire-Whittier and Ventura Boulevard corridors. Shortly after implementation, operating speeds on the Wilshire-Whittier line increased 29 percent, while ridership increased 33 percent. In the Ventura Boulevard corridor, operating speeds increased by 23 percent, and ridership increased by about 26 percent. It has been estimated that between one-third and half of the increased ridership came from travelers new to transit, while about two-thirds of the travel-time savings came from wider spacing between bus stops (Metro, 2000).

By the middle of 2005, Metro had implemented an additional nine lines, and all but two of the 11 total lines had exceeded the projected benchmark of a 20-percent travel-time reduction (Fox and Gephart, 2005). According to the same evaluation report, the 175 miles of Metro Rapid service showed an average speed improvement of 25 percent, effectively translating to a 25-percent increase in capacity (in the sense that faster buses could make more runs every day) at nearly the same operating costs.

To date, the program has grown to 18 lines of arterial-based Metro Rapid service and one dedicated busway, the Metro Orange Line, which

is an extension of the Metro Red Line subway. Most Metro Rapid services provide distinctive bus shelters or signposts along with electronic next-bus-information signs, and all Metro Rapid buses are integrated into the automatic vehicle-locator (AVL) system with signal prioritization at traffic lights. All Rapid vehicles also incorporate a well-defined BRT image with consistent color, logo, and design and are operated using headway-based schedules with high-frequency service.

In November 2006, Metro and LADOT initiated a study on the feasibility of providing bus-only lanes along Wilshire Boulevard from the border of Santa Monica to just west of downtown Los Angeles. The study identified specific hot spots of bus delay along the 12.5-mile-long corridor and proposed a variety of measures to improve speed and reduce travel times (Gephart and McAllester, 2007). The study included the three jurisdictions with responsibility for various segments along this stretch of Wilshire Boulevard, including the City of Los Angeles (9.0 miles), the City of Beverly Hills (2.9 miles), and L.A. County (0.6 miles). The study projected that significant improvements in bus travel times would result from the creation of bus-only lanes in both directions. For example, in the City of Los Angeles and L.A. County segments, end-to-end bus travel times were projected to improve by an average of nearly 15 minutes, or 30 percent. Metro Rapid bus speeds over the entire corridor were projected to increase by an average of nearly 35 percent. The study also estimated that the resulting travel-time improvements would stimulate a 10-percent mode shift from auto to transit along this stretch of Wilshire.

In May 2007, the L.A. City Council adopted recommendations to implement bus-only lanes during peak periods and along the study corridor segments in the city's jurisdiction. In August 2007, the city council approved a recommendation to work with Metro and submit the corridor project for fiscal year 2008 Very Small Starts funding from the Federal Transit Administration. At the time of proposal submission, Metro had not begun discussions with the City of Beverly Hills, so segments in Beverly Hills city limits were not included in the grant application (Gephart and McAllester, 2007). It remains to be seen whether Beverly Hills will support bus-only lanes through its jurisdiction.

Metro Rapid currently operates in L.A. County, including the city of Los Angeles, and 19 other cities. When complete, the Metro Rapid network will serve 35 cities and L.A. County. By 2008, it is expected to operate on 26 identified corridors, covering 450 road-miles.

Interaction with Other Strategies

BRT offers a viable alternative to the automobile for many trips and thus complements strategies that aim to reduce single-occupant driving during peak hours. This would include mandatory employer trip-reduction programs (see Appendix B16), driving restrictions (see Appendix B17), cordon congestion tolls (see Appendix B19), variable curb-parking rates (see Appendix B20), employer parking cash-out (see Appendix B21), and local fuel taxes (see Appendix B22). In addition, BRT works well with many of the strategies that attempt to enhance transit and other alternative modes, such as variable transit fares (see Appendix B23), deep-discount fare programs (see Appendix B24), bus-route reconfiguration (see Appendix B26), and pedestrian improvements (see Appendix B27).

The success of BRT operations can be further supported through such strategies as incident management (see Appendix B10) and rapid towing of curbside parking–restriction violators (see Appendix B7). Metro collected ATISAC-generated data on Metro Rapid bus times on Ventura Boulevard both before and after the Tiger Team (rapid towing program) intervention, and the data indicated an average running speed improvement of more than 2 mph after the Tiger Team treatment (Kumar, 2007). To further enhance enforcement, cameras could be mounted to BRT vehicles to photograph, for ticketing purposes, license-plate numbers of cars that are illegally parked or driving in bus-only lanes.

Restricting curb parking (see Appendix B7) and switching two-way streets to one-way operation (see Appendix B8) may offer opportunities to create BRT bus-only lanes on the arterial system. BRT operations can also take advantage of HOT lanes (see Appendix B18). Signal timing and control improvements (see Appendix B2) can facilitate signal prioritization, another important BRT feature.

Bus-Route Reconfiguration

Restructuring bus service to better serve travel needs is one strategy for increasing transit mode share. Restructuring involves systemwide efforts to remove redundant or underutilized services, combine lines that serve nearby areas, and introduce new lines or services in needed areas. The specific changes made during the process of restructuring are often intended to help reconfigure the underlying logical structure of the network. Possible network structures include radial systems with or without circumferential routes, grid systems, hub-and-spoke systems that feature trunk lines between hubs and local feeder lines serving hubs, and systems that use some combination of the three. Radial systems are not discussed at length in this book because they are best suited for monocentric cities organized around a single, large CBD (Ceder, 2007); land-use patterns in Los Angeles, in contrast, are too polycentric for this approach.

Hub-and-spoke configurations consist of multiple-transfer activity centers (hubs) served by various transit lines (spokes) that connect either to other transfer centers or to local neighborhoods around each hub. This configuration is used extensively in the airline industry, for example. In transit networks, major activity hubs can include transfer stations for multiple bus lines and operators, and major hubs are often linked to each other by higher-speed and higher-capacity trunkline services, such as rail or express buses. When using a hub-and-spoke system, a rider might take a local feeder bus line to reach the nearest major hub, transfer to a high-capacity rail line to reach another hub, then transfer to another local feeder bus line to reach the final destina-

tion. Hub-and-spoke service tends to work best when there is significant demand for travel between different hubs and when the activity centers are not evenly distributed across the landscape. One disadvantage of a hub-and-spoke system, however, is that it requires passengers to transfer more frequently between lines. To minimize transfer wait times, a high level of on-time performance (for both arrivals and departures) is therefore necessary. To achieve such performance, systems that use hub-and-spoke configurations may employ a strategy of timed transfers, where buses arrive and depart on schedules specifically designed to coordinate and synchronize transfers. This is critically important because riders perceive wait and transfer times to be about twice as burdensome as in-vehicle times (Cervero, 1990).

Another possible configuration for bus routing is based on a grid system of transit lines running along the major axes of the road network—for example, north-south and east-west. To reach any destination, a traveler might use a north-south line followed by an east-west line, or vice versa. Bus services on a grid are most effective in areas where activities are more evenly distributed. Grid systems require fewer transfers in general, but longer bus routes may be subject to more congestion delays and less-reliable scheduling.

Ongoing suburbanization of U.S. metropolitan areas with dispersed origins and destinations makes grid-based transit service increasingly costly to provide. In response, many cities, such as Boise, Idaho, Sacramento, California, and Seattle, Washington, have implemented hub-and-spoke plans (Pratt and Evans, 2004). However, most cities' transit services fall somewhere on the continuum between pure hub-and-spoke and pure grid systems, offering some features of both.

Metro is currently reconfiguring its bus service from a (largely) grid network to a hub-and-spoke system to make better use of its growing rail system. The restructuring effort, Metro Connections, aims to (1) retain or improve system performance with shorter bus routes while (2) reducing operating costs by eliminating duplication and underutilized lines. Specific strategies employed by the restructuring effort include eliminating duplicative lines, increasing the level of service (e.g., more-frequent buses) for heavily patronized lines, using high-capacity buses to increase capacity and reduce driver hours, operating

more high-speed services, simplifying and shortening routes, improving downtown services, and increasing overall scheduling efficiency. Metro Connections creates hubs at rail-line stations and other activity centers and uses lower-capacity vehicles to provide spoke service into these hubs. The program classifies transit services based on a tiered system, in which high-capacity lines, such as Metro Rail and Metro Rapid, serve as long-haul trunk service (tier 1 services). Local buses (tier 2) act as feeders to the tier 1 lines and are, in turn, supported by community shuttles and circulators (tier 3). Metro Connections also includes new hub-to-hub services to meet the demand for travel between activity centers.

Evaluation of Strategy

Cost/Revenue Implications

Rating: Medium revenue. Transit restructuring, as currently planned for Los Angeles (see additional discussion under the “Current Status in the L.A. Region” section) is expected to produce substantial cost savings by eliminating underutilized or duplicative lines. Because a portion of the savings will be redirected to increased service in higher-demand corridors, however, overall system ridership is projected to increase as a result of the changes.

The first set of service changes associated with the Metro Connections program was implemented in June 2007, and additional changes will be instituted in 2008 and 2009. Analysis conducted by Metro suggests that the reductions in service for underperforming or duplicative lines in the first phase of changes will lead to an annual loss of around 280,000 boardings (or unlinked trips), while the new or improved services in higher-demand corridors will stimulate an additional 1.9 million boardings per year (Clifford and Albarran, 2007). A net increase in ridership should lead to higher revenues, both through fare-box receipts and regional transit subsidies that factor ridership into the allocation formula. Note that it is difficult to predict exact changes in ridership resulting from the restructuring effort, as system ridership

was also affected by the Metro fare increases that became effective on July 1, 2007.

Service modifications for the first phase of the Metro Connections implementation in June 2007 were predicted to reduce annual service hours by close to 100,000 hours, producing an annual cost savings of \$7.5 million. This phase consisted primarily of adding new Metro Rapid and Metro Rapid Express lines and canceling low-ridership and duplicative lines. By June 2008, the agency expected to have completed the expansion of the Metro Rapid program, to have implemented a downtown restructuring plan, and to have identified scheduling inefficiencies and policies for adjusting the frequency of service along different lines. This phase is estimated to save an additional 215,000 annual service hours and \$16.1 million per year. By June 2009, the agency will eliminate an additional 58,000 service hours while implementing new point-to-point services and fine-tuning previous restructuring efforts—resulting in a further \$4.3 million in annual cost savings (Clifford and Albarran, 2007).

Short-Term Effectiveness in Reducing Congestion

Rating: Low. Bus-reconfiguration efforts can successfully shift drivers from their cars if the routes and capacity levels match travel demand and patterns and if the service is competitive with driving in terms of cost, convenience, reliability, and door-to-door travel times. In Los Angeles, even under best-case assumptions about the ability to match service with travel demands, short-term reductions in congestion are likely to be modest, because most bus services operate in mixed-flow lanes, subjecting buses to the same congestion delays as automobiles. Also, because the number of trips made by automobile far exceeds the number of trips made by bus, even dramatic increases in transit boardings translate into small percentages in reductions of automobile trips (Wambalaba, Concas, and Chavarria, 2004). Additionally, a major concern in service restructuring is whether changes in service will force existing riders to change their travel patterns and thus increase the risk of *losing* existing riders (Pratt and Evans, 2004).

Long-Term Effectiveness in Reducing Congestion

Rating: Low. If service restructuring successfully matches future growth in travel demand, ridership may grow over time because the new service will provide additional capacity and more options for travel. Unless complementary policies that internalize the full costs of driving (such as parking fees, congestion tolls, or VMT fees, for example) are put into place, however, the effects of triple convergence can be expected to undermine any long-term congestion relief from improved transit operations.

Mobility, Accessibility, and Traveler Choice

Rating: Good (uncertain). The specific effects for mobility, accessibility, or traveler choice that result from transit-system reconfiguration are obviously tied to the specific system-design choices made. In particular, the effects depend largely on how well a transit agency assesses current riders' and nonriders' travel patterns and needs and matches service restructuring to meet those needs. In general, if the intent is to replace underperforming lines with increased service and higher-capacity vehicles in areas of higher demand—which is the stated goal of the Metro Connections program—the overall effects on travel-related goals should be positive, thus leading to a rating of *good*. In the specific case of L.A. Metro, however, the agency is eliminating more service than it is adding (hence the overall cost savings described earlier). While clearly beneficial from a budgetary perspective, this makes the travel-related effects less certain. Analysis conducted by Metro staff suggests that the gains in ridership produced by the added service in areas of higher demand will more than offset the losses associated with the discontinuation of underutilized or duplicative service, and this may well be true. Confirming this proposition, however, would require detailed travel-demand forecasting—a task beyond the scope of this study—so we characterize the rating of *good* as being *uncertain*.

Safety

Rating: Neutral. Transit restructuring has neutral safety effects because this practice generally involves rerouting buses using the same

vehicles and same road infrastructure. This neither adds nor eliminates potential safety risks.

Economic Efficiency

Rating: Good. One of the primary goals of transit-system reconfiguration is to reduce or eliminate service for underutilized lines and introduce or enhance service in higher-demand corridors. This enables a transit operator to serve a greater number of passengers for a given level of resources, thereby improving economic efficiency.

Environment

Rating: Good. Transit-system reconfiguration can produce environmental benefits in several ways. First, if the reconfiguration results in better system performance and this leads more people to use transit instead of driving, there should be some net reduction in emissions from the transport sector (though the effects of triple convergence on the road system may limit such savings over time). Second, if bus service is eliminated or reduced on underperforming or duplicative lines and replaced with additional service in higher-demand corridors, average occupancy for transit vehicles should increase, thereby reducing emissions per passenger-mile. Third, if the reconfiguration leads to greater patronage on the heavy and light rail lines, which produce fewer emissions per seat-mile than buses, then there should be further reductions in emissions. Finally, well-planned reconfiguration of the bus routes may make it possible to reduce deadheading—bus trips without passengers between the bus yard and a service route to begin or end service or between the end of one line and the beginning of another between runs. Any reduction in deadheading will also reduce overall system-wide emissions.

Equity

Rating: Good (uncertain). Lower-income and other underrepresented groups tend to rely on transit more heavily than other segments of society do. Provided that system-reconfiguration efforts result in more-effective transit service overall, such groups should be, in general, better off. For this reason, we rate the equity effects of this strat-

egy as *good*. Note, however, that system reconfiguration involves reducing service in some areas while improving service in others. It would be difficult to determine specific equity outcomes without examining more closely the demographic characteristics of groups that will receive worse service and groups that will receive better service after the reorganization. Because such analysis was beyond the scope of this study, we characterize our rating of *good* as being somewhat *uncertain*.

Stakeholder Concerns

Rating: Medium/can partially address—>low. Significant reconfiguration of the transit system is likely to raise a moderate level of stakeholder concerns. Individual riders may express opposition to the restructuring if it will remove or cut back on services on which they rely, increase their travel times, or increase their transit fares. Organized bus rider–advocacy groups, in turn, may oppose any system-wide reductions in service for transit-dependent populations. Opposition may be reduced if more-convenient services replace cut services or if the cost savings are ultimately used to fund other programs that improve transit. These strategies will, however, only partially address stakeholder concerns, since (1) any systemwide change will likely make some individuals worse off and, (2) prior to implementation and subsequent evaluation, riders (and rider interest groups) may be skeptical of the outcomes.

General Political Obstacles

Rating: Medium/can be fully addressed—>low. Opposition from elected officials or voters is likely to be low unless restructuring disproportionately removes or adds services across jurisdictions. Uneven distribution of transit services to various districts may be justified in terms of matching transit supply to demand, but it is also likely to cause concern among elected officials who are responsible for delivering and safeguarding public services for their constituents.

This can be fully mitigated, however, by providing equal (or nearly equal) distribution of service to all districts, sectors, and jurisdictions. According to a Metro representative, the method used to identify transit hubs for the Metro Connections program was based on population

and employment densities (trip origins and destinations) in each traffic-analysis zone (TAZ).¹ The initial stage of this analysis found that all major activity centers were located in Metro's Westside and central sectors. To ensure political acceptability, Metro staff then ranked and screened for top activity centers in each of Metro's other three service sectors to produce the final set of transit hubs (Clifford, 2007a). Metro's board of directors ultimately approved this plan.

Institutional Obstacles

Rating: Low. Institutional obstacles to transit reconfiguration are not likely to be significant, though there may be a few issues to consider. For instance, while Metro is responsible for identifying hubs and rerouting services to these hubs, the actual siting and design of transit stops are often under the control of local jurisdictions. To maximize service efficiencies through transit restructuring, it will therefore be important to obtain the consent and cooperation of local jurisdictions.

Municipal transit operators (other than Metro) were initially expected to object to restructuring because it would increase the loads on their systems ("MTA Weighs 'Hub and Spoke' Routes," 2003). For example, if Metro eliminates service on a line that duplicates another municipal operator's line, the municipal operator may then experience increased loads and be forced to add capacity. As the Metro Connections plan has unfolded, however, Metro has found that municipal operators generally support the restructuring. Reductions in service tend to be focused on shared corridors where municipal services already have established routes, and, as municipal operators increase their service hours, they also receive more regional funds that are allocated based on a formula that rewards high service levels and low fares.²

¹ TAZs are small geographic units that agencies, such as SCAG and Metro, use in transportation models. There are approximately 1,700 discrete TAZs in L.A. County.

² Recent changes to the region's allocation formula now ensure that operators receive their allocations in a timely manner, making it more feasible and attractive for municipal operators to willingly add service where needed. Prior to the change, allocations experienced a two-year lag. Also, Metro's average operating cost is substantially higher than that of municipal operators, making it attractive to shift service to local operators where there is service duplication (Clifford, 2007b).

Other institutional issues will include land assembly for transit hubs,³ and Metro is currently negotiating with developers to provide land dedications in exchange for reductions in automobile-parking requirements. This has been a successful effort for the most part and may be a likely strategy for mitigating institutional obstacles to hub development in newly developing areas.

Current Status in the L.A. Region

Rating: Significant. As discussed, L.A. Metro is currently implementing the Metro Connections program, a systemwide transit-restructuring effort intended to increase ridership and improve operating efficiencies. The impetus for this restructuring is to consolidate bus services with the new high-capacity transportation options that have been developed in the past decade, including Metro Rail, Metro Rapid, and expanded commuter-rail operations. Some of the key strategies are to feed more riders into the expanded rail system by placing bus hubs at rail stations. This would allow the agency to save money by eliminating some bus routes that duplicate rail-line service. Another key strategy is to increase investments in heavily patronized service by adding higher-capacity vehicles, such as 60-foot articulated buses, thereby bolstering overall system capacity without significantly increasing operating or maintenance costs. The agency will also review and discontinue lines that are performing poorly or are duplicative; shorten, streamline, and simplify routes to increase on-time performance; improve services in the downtown area; and increase scheduling efficiency. The overall goals of Metro Connections are to increase ridership and to improve efficiency by making the best use of existing capacity. Two measurable objectives are to (1) increase bus-system speed by 1 mph to reduce travel times and operating costs and (2) to increase seat-capacity utilization from 36 to 40 percent.

The restructuring program began with a needs assessment completed in January 2004 that identified transit users' and nonusers' concerns. Needs included more-reliable schedules, faster travel, and lower aggregate travel times (Catoe, 2006). The agency then identified 19

³ *Land assembly* is the process of acquiring land, often including multiple adjacent parcels.

regional centers of activity that will serve as transit hubs. These centers are geographically distributed, spread throughout Metro's five transit-service sectors in the county. The selection of hubs was based on modeling analysis that included data on trip origins and destinations, work and home trips, and employment densities. Activity centers were then screened and ranked. Initial evaluations found that the top activity centers were located primarily in the Westside and central sectors. Subsequently, the same analysis was performed individually for each sector, and the top centers in each sector were identified, to produce 17 regional centers. Two other centers were also selected based on anticipated future growth. In total, 19 regional centers were identified.

Metro then created a detailed service plan and identified resources needed to implement the restructuring. Metro Connections' first phase rolled out in June 2007, and, by working with municipal operators through sector working groups, Metro estimates close to 100,000 hours of savings, a 1.5-percent efficiency gain. Changes that required the least time and disruption to the system were prioritized into the first phase of implementation, and later phases are expected to include lines that are more complicated but would also have larger savings potential (Clifford, 2007a). As of this writing, the agency has not conducted an evaluation of Metro Connections targets, in part because only the first phase of changes has been completed and in part because the recent Metro fare increase in June 2007 is likely to have had a confounding effect on changes in ridership. Full implementation of the Metro Connections program is expected in June 2009.

Interaction with Other Strategies

Transit reconfiguration could complement many of the strategies intended to reduce the demand for driving, including mandatory TDM programs (see Appendix B16), driving restrictions (see Appendix B17), cordon congestion tolls (see Appendix B19), variable curb-parking rates (see Appendix B20), employer parking cash-out (see Appendix B21), and local fuel taxes (see Appendix B22). Reconfigured routes also could work alongside (and benefit from) such strategies as signal synchronization (see Appendix B2), BRT (see Appendix B25), deep-discount fare programs (see Appendix B24), and HOT lanes (see Appendix B18).

Pedestrian Strategies

The goals of pedestrian strategies include making neighborhoods more vibrant and walkable, improving pedestrian safety, and shifting some trips from vehicles to walking. About one-quarter of all trips in the United States are one mile or less in length, and 75 percent of these are currently made in vehicles (Deary, 2003). Shifting these trips to walking would decrease VMT at the neighborhood level.

A key ingredient in making walking more attractive, although not a specific transportation improvement, is the creation of mixed-use, medium- to high-density neighborhoods, where residences are close to shopping, restaurants, offices, child care, and schools. It is not realistic to think that pedestrian mode share will increase in a single-use development pattern in which the only destinations are other residences, regardless of the quality of pedestrian infrastructure.

Given that such changes in land-use patterns can take decades to implement, this discussion focuses on shorter-term measures to improve pedestrian conditions in potentially walkable neighborhoods. These measures, following a typology offered by FHWA (Harkey and Zeeger, 2004), are outlined here.

- *Pedestrian infrastructure:* This includes providing basic infrastructure, such as sidewalks, pedestrian crossings and islands, and curb cuts.
- *Roadway and intersection design:* Engineers can take a number of steps to ensure that roadways and intersections are safe and accessible for pedestrians as well as for vehicles. Options include narrowing vehicle-travel lanes, reducing the number of lanes,

allowing on-street parking, designing driveways that encourage good sight lines and crossings, and creating smaller curb radii (forcing drivers to turn more slowly) and smaller right-turn slip lanes (the lanes vehicles use to wait to turn right at high-volume intersections).

- *Traffic calming*: Traffic calming includes a suite of strategies for reducing the speed of traffic in pedestrian zones such that pedestrian-vehicle collisions are less frequent as well as less severe. In pedestrian-vehicle collisions, the fatality rate to the pedestrian is only 5 percent if the vehicle is traveling 20 mph but increases to 85 percent if the vehicle is traveling 40 mph (TRB, 1998). The following techniques fall under the heading of traffic calming (Fehr and Peers Transportation Consultants, undated):
 - *vertical deflections*, such as speed humps, speed tables, raised crosswalks, and textured pavement
 - *horizontal deflections*, such as roundabouts, chicanes (curb extensions that alternate to form S-shaped curbs), and intersection realignments
 - *horizontal narrowing*, such as neckdowns (curb extensions that effectively reduce the right-of-way at an intersection), chokers (similar to neckdowns but midblock), and center islands
 - *volume controls*, such as diverters, half and full street closures, and median barriers, that reduce the number of vehicles allowed to enter a neighborhood.
- *Signage and signal timing*: Measures in this category include timing traffic signals to allow adequate pedestrian-crossing times, installing pedestrian signals, creating a signal phase to allow pedestrians to cross in all directions (sometimes called a *pedestrian scramble*), giving pedestrians an advance walk signal, and prohibiting right turns on red.
- *Enforcement*: In addition to physical measures, pedestrian improvements may require enforcing vehicle stops at crosswalks and speed limits.

Pedestrian improvements can range from making a dangerous intersection safer to creating a pedestrian-only environment, such as

Santa Monica's Third Street Promenade. The type and scale of the improvements should be correlated with the desired pedestrian impact. For example, traffic calming is more appropriate for residential neighborhoods and shopping districts than for major arterials. Similarly, the pedestrian scramble makes the most sense for intersections with high volumes of pedestrians.

While vehicle-only facilities, such as freeways are not appropriate places for pedestrian improvements, high-volume arterials can be made into multiway boulevards that move fairly high traffic volumes (in the range of 50,000 to 75,000 vehicles in each direction per day) while accommodating pedestrians. Such boulevards can be accommodated within a right-of-way of approximately 100 to 200 feet (Jacobs, Rofe, and MacDonald, 1995). This is a preferable solution to grade separation (i.e., creating pedestrian overpasses or underpasses). Such facilities can be underused because of real or perceived dangers, and they send a subtle (if unintended) message to pedestrians that moving vehicles is more important than moving people on foot.

Evaluation of Strategy

Cost/Revenue Implications

Rating: Medium cost. The capital cost of pedestrian improvements varies depending on the nature of the specific improvement. Some pedestrian-safety improvements (such as signal timing and striping for on-street parking) can be made at relatively low costs, while others (such as changing the geometry of turn radii or slip lanes or adding sidewalks where none currently exists) can be more expensive. Most pedestrian strategies involving physical improvements would have fairly low operating costs, consisting mainly of routine maintenance. Enforcement would have higher operating costs, although some enforcement can be automated and presumably less costly (for example, cameras to enforce crosswalk right-of-way).

Though many individual pedestrian improvements are fairly low in cost, the total expense involved in widespread deployment of pedes-

trian improvements in appropriate locations throughout the region would quickly mount, thus meriting a cost rating of *medium*.

Short-Term Effectiveness in Reducing Congestion

Rating: Low. Even places that function well as pedestrian environments still experience traffic congestion, and even with good pedestrian facilities, many vehicle trips are too long to switch to walking trips. Therefore short-run pedestrian strategies are considered to have a *low* impact on congestion.

Long-Term Effectiveness in Reducing Congestion

Rating: Low. While most of the evidence regarding roadway and intersection design and traffic calming is focused on pedestrian safety, there is some evidence that walkable neighborhoods result in a small decrease in vehicle travel. While there are complex interactions between neighborhood characteristics of “density, design, and diversity,” one review of studies found that, for every 10-percent increase in density, vehicle trips and VMT by neighborhood residents decreased by 0.05 percent (Ewing and Cervero, 2001). Another study found several neighborhood characteristics that increased the probability of walking: more than three types of businesses in a neighborhood, a housing density greater than 14 units per acre, and a higher percentage of four-way intersections (Boer et al., 2007). However, these impacts would be most noticeable at the neighborhood level. Land-use changes that foster more walkable neighborhoods might have a slightly larger long-term impact, but these impacts would be localized and not expected to reduce overall regional congestion.

Nationwide, walking has declined as a share of work trips more than any other mode, from just over 5 percent in 1980 to less than 3 percent in 2000 (Pisarski, 2006). Even if the pedestrian mode share were to increase dramatically, triple convergence would likely erode any short-term benefits in traffic reduction.

Mobility, Accessibility, and Traveler Choice

Rating: Good. Improving pedestrian conditions has a positive impact on accessibility, to the extent that locations previously inacces-

sible on foot can be made accessible. Pedestrian improvements can also benefit people who cannot or do not drive.

Many public-health researchers believe that increased use of walking and bicycling would contribute to a general improvement in public health and a decline in obesity (VTPI, 2008c).

Safety

Rating: Bad/can partially mitigate—>neutral. Walking is generally more dangerous than driving on a miles-traveled basis. According to one national analysis, there are 1.3 fatalities per 100 million miles traveled for passenger cars and trucks but 20.1 pedestrian fatalities for the same 100 million miles traveled (Ernst, 2004). However, many strategies can be employed to improve pedestrian safety (Harkey and Zeeger, 2004; Pucher and Dijkstra, 2000). When investing in pedestrian facilities, safety features should clearly receive a significant level of attention.

Economic Efficiency

Rating: Neutral. Increasing pedestrian activity would not likely have a significant effect on economic efficiency.

Environment

Rating: Good. To the extent that some trips can be shifted from motorized to nonmotorized modes, this strategy would result in a decrease in emissions. Eliminating multiple short trips has a greater environmental benefit than eliminating a single long trip, since approximately 20 to 25 percent of emissions are produced during the first few minutes of driving. This is because emission-control equipment operates most efficiently once the vehicle has been running longer.

Equity

Rating: Good. Low-income residents are less likely to own vehicles than are wealthier residents, so improvements in pedestrian facilities and safety tend to benefit these groups. In several cities where the ethnicity of pedestrians killed in traffic crashes has been studied, Latino deaths are disproportionate to their population; in an Atlanta study,

for example, the pedestrian death rate was six times higher for Latinos than whites (Ernst, 2004). In the late 1990s, the Southern California city with the highest pedestrian death rate was Santa Ana, which has a high population of Latino immigrants (Morosi, 1999). To the extent that lower-income African Americans and Latinos are more likely both to be pedestrians and to suffer higher rates of injury and death, a focus on pedestrian safety would constitute an equity gain.

Stakeholder Concerns

Rating: Medium/can partially address—>low. Many improvements to pedestrian conditions (such as traffic-calming measures) result in slower travel times for vehicles, which may anger drivers. In the same vein, there may be tensions between citizen groups or other advocacy organizations that espouse pedestrian safety and traffic or public-works departments that see the efficient movement of vehicles as their top priority. Generally speaking, the more quickly a roadway moves vehicles, the more dangerous it is for pedestrians, which sets up a clash over which roadways should be made pedestrian-friendly. Conflicts over these issues often arise regarding urban arterials, which carry heavy traffic volumes yet also contain destinations (offices and stores) that pedestrians can access. The boulevard concept suggested earlier might be one way to approach this problem on certain arterials, although this would be a longer-term solution.

In addition, fire and rescue departments tend to be hesitant to approve narrow streets or traffic-calming devices out of concern that emergency vehicles may have problems with access. There may be other means to help ensure access, such as smaller response units, better enforcement of parking restrictions, and low curbs over which trucks can drive in emergencies (Crawford, 2006).

Bicyclists sometimes oppose the provision of on-street parking, which both calms traffic and separates sidewalks from traffic lanes, because drivers and driver-side passengers getting out of parked cars may open their car doors into a bicycle lane.

Stakeholder concerns can be partially addressed by carefully selecting the streets on which to emphasize pedestrian and bicycle activity and ensuring that streets with high traffic volumes are not made more

congested. Transportation planners can also work with fire and rescue departments to show their staff how emergency-access concerns can be addressed; this might include demonstrations of vehicle access or arranging for fire and rescue staff to speak with counterparts in another jurisdiction with narrower streets.

General Political Obstacles

Rating: Low. To the extent that widespread implementation of pedestrian improvements would lead to significant reductions in average vehicle-travel speeds, drivers might raise political objections. On the other hand, such improvements can also lead to greater pedestrian safety and more vibrant and walkable neighborhoods, outcomes that many residents would favor. On balance, while there may be some political obstacles, the general level of political resistance is likely to be *low*.

Institutional Obstacles

Rating: Low. For local roads, the level of institutional obstacles is not likely to be significant. Note, however, that some of the larger urban arterials, such as Santa Monica Boulevard, are state roads, and, in such cases, the authority to implement engineering changes will lie with Caltrans. Cooperation with Caltrans may also be needed on such issues as signal timing if local roads intersect with state ones.

State law also governs other issues, such as maximum fines for moving violations. The current California state fine for not stopping at a crosswalk is currently \$270 for a first offense; if a pedestrian is injured as a result, the fine increases to \$594 for a first offense (“Can You Spot the Cop in the Crosswalk?” 2001).

That said, a large percentage of the roads on which one might implement pedestrian improvements fall under local jurisdiction. We thus rate the potential for institutional obstacles as *low*.

Current Status in the L.A. Region

Rating: Moderate. The City of Los Angeles has officially designated three pedestrian-oriented districts in Atwater, in the Westwood-Pico area, and on Westwood Boulevard. The districts are meant to

encourage pedestrian activity through such features as street trees and landscaping, benches, trash receptacles, pedestrian-oriented lighting and signage, attractive paving materials, bicycle amenities, and other “slow-street” techniques (LADCP, undated). The City has also drafted downtown urban-design guidelines and standards, which include provisions for wide sidewalks and active uses for the front of parking structures. As of this writing, the guidelines have not yet been adopted (George, 2007). Many other cities in the region have pursued pedestrian improvements even more aggressively. Santa Monica, for instance, has deployed numerous pedestrian-oriented street features, such as roundabouts, neckdowns, crosswalk medians, and road closures. LACDPW (undated) also operates the Neighborhood Traffic Management Program, through which residents can request traffic-calming measures for their neighborhoods.

Interaction with Other Strategies

Despite potential minor conflicts, pedestrian and bicycle strategies (see Appendix B28) are often discussed and implemented in tandem as ways to increase the use of nonmotorized modes. Pedestrian strategies are also often linked to improvements in transit (see Appendixes B25 and B26). On the other hand, efforts to make neighborhoods and intersections safer for pedestrians may come into conflict with strategies to increase the automotive capacity and speed of the road network, such as signal synchronization (see Appendix B2) and the elimination of curb parking (see Appendix B7).

Bicycling Strategies

Bicycling is a nonmotorized mode and a potential substitute for vehicular trips up to several miles. While cities can do much to encourage recreational cycling, this section focuses on bicycling as a travel mode to replace automotive trips. Along these lines, cities can pursue a number of bicycling strategies:

- *Bicycle facilities and networks:* These include both on- and off-road lanes and trails. When facilities are interconnected, bicyclists can travel easily throughout a city or region. Some jurisdictions have implemented bicycle boulevards, which allow local auto traffic but discourage through traffic, and combined bicycle/transit lanes.
- *Bicycle-friendly intersections:* Sight lines and signal timing can contribute to whether intersections are safe for bicyclists. In some cities with well-developed bicycle infrastructure, bicycles have a dedicated signal phase.
- *Bicycle storage:* Especially for urban areas, safe and secure storage areas for bicycles are important. These may be on-street bicycle racks, bicycle lockers in public areas (such as rail stations), private storage at employer sites, or guarded bicycle parking.
- *Bicycle access to transit:* Buses can be outfitted with bicycle racks, and rail policies can allow passengers to carry bicycles on board the trains. This can contribute to increased transit use and eliminate vehicle trips for access to transit.
- *Bicycle-rental programs:* Several cities have free or low-cost bicycle-sharing programs in which people can pick up a bicycle at a designated spot and return it elsewhere. These cater to short trips.

In addition, many of the pedestrian improvements discussed elsewhere in this document are also applicable to safe bicycling, including roadway and intersection design, traffic calming, and enforcement.

Most cities in the United States have some type of bicycling facilities and programs in place, although their degree of use depends in part on factors beyond the city's control, such as terrain and weather. These can range from minimal measures to large-scale bicycle networks, public storage, and dedicated bicycle plans and planners. Many large European cities have well-developed bicycle strategies; for example, Berlin and Stockholm have extensive on-street bicycle lanes, and Paris recently started a 10,000-bicycle rental program.

Evaluation of Strategy

Cost/Revenue Implications

Rating: Low cost. Compared to infrastructure for vehicles, bicycling infrastructure is not expensive. Capital costs fall into three main categories: on-street facilities (bike lanes), off-street facilities (bike trails), and equipment (e.g., signage, bike parking). Adding bike-lane striping on existing roads, assuming that sufficient right-of-way exists, costs very little. The construction of new bike paths, including paving, typically varies between \$100,000 and \$300,000 per mile.¹ Bicycle facilities also require modest ongoing maintenance costs.

Bicycling does not generate revenue, unless paid bike parking is provided. Metro charges \$25 per year to rent a locker, while Metrolink lockers are free. In Long Beach, a secure bicycle-parking facility called Bikestation charges members \$12 per month or \$96 per year. According to one article, these fees along with other revenue sources cover two-thirds of the operating costs (Steptoe, 2007).

Note that our rating of *low cost* assumes that jurisdictions in Los Angeles would expand the bicycle network largely through the creation of bike lanes on existing roads; if a significant number of miles of new paved bike paths were created, the costs would be higher.

¹ See the bicycle-facility cost estimator created by HSRC (undated).

Short-Term Effectiveness in Reducing Congestion

Rating: Low. In some European cities with good bicycling infrastructure, bicycling constitutes a fairly sizable share of all trips. For example, in Copenhagen, 30 percent of all trips are made by bicycle (Smith and Hatch, 2006). In contrast, in the United States, bicycling represents only 0.8 percent of all trips (FHWA, 2004). There should be room for the L.A. region's bicycle mode share to grow, as the climate allows year-round cycling. However, an increase of the magnitude required for significant congestion reduction is improbable in the near term.

Long-Term Effectiveness in Reducing Congestion

Rating: Low. The success of bicycle programs at relieving congestion depends on the nature of the trips that can be shifted from vehicles to bicycles. At the national level, the average bicycle-trip length is two miles (Pucher and Renne, 2003), while the average commuter-trip length is closer to 12 miles (Hu and Reuscher, 2004). In the six-county SCAG area, the average one-way commute trip is 19.2 miles, and the proportion of commute trips made by bicycle is 0.5 percent, a figure that has been fairly constant for the past decade (SCAG, 2006). Given the trip lengths, it seems unlikely that a large proportion of commute trips could be shifted to bicycle without very substantial changes in land use that create more opportunities for residents to live closer to their workplaces.

In other regions of the United States, bicycle commute shares seldom rise above a few percentage points. In St. Paul–Minneapolis, one study found that, after specific bicycle facilities were constructed, the bicycle commute share rose from 1.7 to 2.0 percent, while the rest of the region remained at 0.2 percent (Barnes and Thompson, 2006). The U.S. city commonly thought to have the highest bicycle-commuter mode share is Davis, California. According to the city's bicycle plan, the share of commute trips made by bicycle is 17 percent (City of Davis, 2006). The success of bicycling is generally attributed to the small land area, large student population, and the investments the city has made in bicycle lanes; mild weather and flat topography are also contributing factors.

Greater potential exists for bicycling to eliminate short vehicle trips for errands, visiting friends, and the like. According to one survey, of all bicycle trips made in the United States, nearly 60 percent are for recreation or exercise; commute trips (including school) made up only 5 percent (NHTSA and BTS, 2002). However, it is difficult to determine an upper bound for the number of people who might begin bicycling with better facilities or programs. One study suggested that the best-fit formula is 0.3 percent plus 1.5 times the bike commute share (for SCAG, this would be 1.05 percent). However, the study also commented on the inherent difficulty of trying to forecast the use of a particular bicycle facility if built, noting that, even in a single metropolitan area, the percentage of the population that regularly bicycles might differ by a factor of 10 from neighborhood to neighborhood (Krizek et al., 2006).

One survey of participants in a bicycle-sharing program in London found that regular participants already used bikes for a relatively high percentage of commute trips—about 30 percent—even before the program was instituted. Most (68 percent) of the trips taken under the bike-sharing program were leisure trips, with just 11 percent being commute trips. Moreover, most of the shared-bicycle trips substituted for transit trips or walking; only 6 percent of trips would otherwise have been taken by car (Noland and Ishaque, 2006).

Mobility, Accessibility, and Traveler Choice

Rating: Good. Bicycle programs and facilities contribute to increased traveler choice and provide important mobility options for those who cannot or choose not to drive. Many public-health researchers believe that increased use of walking and bicycling would contribute to a general improvement in public health and a decline in obesity (Berrigan et al., 2006; Frumkin, 2005; VTPI, 2008c).

Safety

Rating: Very bad/can partially mitigate—>bad. Bicycle safety is an important issue. While national total bicyclist fatalities have fallen by 6 percent since 1995, 784 bicyclists were killed in traffic crashes across the country in 2005 (the most recent year for which statis-

tics were available). Nearly one-fifth of these were children between ages five and 15. In California, the rate of bicyclist fatalities was 3.18 per 1 million population, higher than the national average of 2.64. While this is much lower than the fatality rate for all traffic fatalities (95 per 1 million population), it does not account for the vast difference in miles traveled in vehicles as opposed to on bicycles (NHTSA, undated[a], undated[b]). According to Pucher and Dijkstra (2000), bicycling fatalities are 11 times higher than car-occupant fatalities on a per-mile basis.

Jurisdictions can take many steps to increase bicyclist safety. One important factor is bicyclist and driver behavior; many safety campaigns stress the theme of vehicle and bicycle awareness, as well as helmet use. However, changes to roadways, such as creation of bike lanes, can also create safe bicycling conditions.

Economic Efficiency

Rating: Neutral. It is not expected that an increase in bicycling would have an appreciable effect on overall economic efficiency.

Environment

Rating: Good. As a nonmotorized mode, an increase in bicycling would have positive environmental impacts. The impact would depend on the number and length of trips for which bicycle use substitutes for driving. Because bicycle trips tend to be shorter in distance and more common for noncommute trips in off-peak hours, it is less likely that the phenomenon of triple convergence—a key limitation of many other traffic-relief strategies—would erode the environmental benefits of increased bicycling.

Equity

Rating: Good. Households without cars—the majority of which fall within lower-income groups—are more likely to use nonmotorized modes. Making bicycling safer and more convenient would thus have slightly positive equity implications. In one study of urban travel, people in households without vehicles make 2.4 percent of their trips

by bicycle, compared to just 0.9 percent of all households (Pucher and Renne, 2003).

The equity impacts, however, are slight. At least in urban areas, people in lower-income households are much more likely to walk or use transit than bicycle. Moreover, even in the lowest income category, under \$20,000, more than 70 percent of households own vehicles. So the slight increase in bicycle use noted in the preceding section does not translate into a large benefit for lower-income households. In fact, people with incomes between \$40,000 and \$75,000 make one-third of all bicycle trips, which suggests that bicycle use is not concentrated in lower-income groups (Pucher and Renne, 2003).

Bicycle use declines with age. For trips in urban areas, 3.2 percent of trips by children aged five to 15 are on bicycle; no other age group is comprises more than 1 percent. Interestingly, in Germany and the Netherlands, the elderly take half their trips by nonmotorized modes, indicating that, with conducive conditions, age does not have to be a barrier (Pucher and Renne, 2003).

Stakeholder Concerns

Rating: Medium/can partially address—>low. Neighborhood associations may object, depending on the type of bicycle facilities or programs introduced. For example, if creating a new bike lane reduced on-street parking spaces, a neighborhood organization might object. Such objections can be offset to some extent by selecting routes for which the addition of bike lanes has less impact on the existing road configuration.

General Political Obstacles

Rating: Low. Depending on the extent of bicycle facilities or programs, there may be more generalized opposition to the notion of spending scarce resources on a mode with a small number of proponents. Some voters or elected officials may have had negative encounters with aggressive bicyclists and engender a negative attitude toward bicycling.

Institutional Obstacles

Rating: Medium/can partially address—>low. Institutional obstacles might exist in the form of difficulties working across city boundaries to develop regionwide bicycle facilities. One strategy for overcoming this obstacle would be to provide regional funding through Metro to cities that agree to develop bicycling facilities that would help improve the regional bicycle network's connectivity.

Current Status in the L.A. Region

Rating: Moderate. California encourages cities to develop bicycle plans by providing funding through the Bicycle Transportation Account (BTA), administered by Caltrans. Approximately \$9 million was allocated to this program in fiscal year 2006–2007, and only cities with bicycle plans can apply for funding. Bicycle plans must meet certain requirements, such as being formally adopted by the city or county and being updated every five years. A county plan can be written such that its constituent cities do adopt it, which would allow them to qualify for BTA funding (Snyder, 2007).

The City of Los Angeles' bicycle plan was last updated in 1996. The plan's stated goal is to increase the bicycle mode share to 5 percent, for all trips as well as for commute trips, by 2015. The bicycle plan forms part of the transportation element of the City's general plan (City of Los Angeles, 1996).

According to the plan, Los Angeles has designated 134 miles of class I bike paths (off-street), 321 miles of class II bikeways (dedicated on-street lanes), and 76 miles of commuter bikeways (shared on-street lanes with preferential use for bicyclists during peak hours), for a total of 531 miles of bike routes. The plan also calls for several bicycle-commuter centers, facilities that provide bicycle parking, repair, and showers. Other objectives relate to expanding bike parking throughout the city at private developments, transit stations, and schools; improved lighting; increased incentives for bicycle commuting; and better funding for bicycle facilities. The plan commits to inter-agency cooperation as well as conducting bicycle traffic counts and monitoring accidents (City of Los Angeles, 1996). However, many of these recommendations have not yet been implemented; for example,

the only bicycle-commuter centers in the region are in Long Beach and Santa Barbara. On the other hand, Los Angeles has made progress in allowing bikes on buses and requiring bicycle parking in commercial developments (Snyder, 2007).

The city also has a bicycle advisory committee, formed in 1974. This committee advises LADOT and the Division of Transportation Planning on issues related to bicycle transportation and plan implementation and works with the Department of Parks and Recreation on recreational-bicycling issues.

Metro adopted a bicycle plan in June 2006. Its goal is to double bicycle ridership, though a specific target percentage is not cited. Objectives include providing technical assistance to local jurisdictions, better incentives for commuter bicycling, and bicycling outreach and safety programs. Instead of focusing on bicycling corridors, it emphasizes access to transit, both in terms of providing bicycle-parking facilities at stations and allowing bicycles to be brought aboard transit vehicles. The plan identifies more than 150 bike-transit hubs at different types of transit stops and with varying infrastructure and makes specific recommendations based on audits of 12 hubs. Finally, the plan identifies gaps in the interjurisdictional bike network throughout the county (Metro, 2006).

As noted, there are two bicycle commuter centers in the region; two others are planned for Pasadena and Santa Monica (Steptoe, 2007). Bikestation, a nonprofit organization that runs guarded bicycle-parking facilities in six West Coast locations, operates the ones in Long Beach and Santa Barbara. In addition to parking, Bikestation offers bicycle rental, repair, and accessories (specific facilities vary with location).

Interaction with Other Strategies

In some cases, pedestrians (see Appendix B27) and bicyclists may conflict. For example, if roadways are perceived as dangerous, bicyclists may ride on sidewalks. Bicycling can be encouraged through better integration with transit, having sufficient bicycle parking at transit stations, and allowing bicycles on transit vehicles. Strategies that raise the cost (or opportunity cost) of car travel, including cordon congestion tolls (see Appendix B19), variable curb-parking rates (see Appen-

dix B20), employer parking cash-out (see Appendix B21), and local fuel taxes (see Appendix B22), will encourage a shift to alternative modes, including bicycling.

Institutional Roles in Transportation Planning and Policy

Transportation policy and planning in Los Angeles involve numerous government entities at the federal, state, regional, and local levels, as summarized in Table C.1. This appendix reviews the specific roles of the most relevant government actors.

Federal-Level Actors

Focusing on the movement of passengers (as opposed to goods), at least two USDOT agencies are directly relevant to transportation decision-making in Los Angeles: FTA and FHWA. EPA, which bears responsibility for enforcing CAA (P.L. 88-206), also plays an important role in transportation policy in the region. This link is reinforced by the requirements of the 1990 CAA amendments (P.L. 101-549), which tie federal funding for transportation projects to conformance with achieving air-quality goals. Additional federal laws with important implications for transportation planning include CRA (P.L. 88-352) and NEPA (P.L. 91-190), which together require consideration of environmental and social-equity concerns during the planning process (Johnston, 2004).

While federal influence is primarily at the level of funding for transit and highway projects in accordance with federal laws, oversight of the environmental-review process for federally funded projects according to NEPA is an important responsibility of federal

Table C.1
Government Actors Involved in Transportation Decisionmaking in Los Angeles

Level of Government	Agency
Federal	USDOT FHWA FTA EPA
State	California legislature BTHA Caltrans California DMV CTC ARB Cal/EPA
Regional (intercounty)	SCAG AQMD
Regional (county)	L.A. County Metro
Regional (intracounty)	COGs in L.A. County SGVCOG GCCOG SBCCOG WCCOG ACTA
Local (city and subcity)	Cities (88 in L.A. County) Neighborhood councils (86 certified, 10 forming in city of Los Angeles) Other transit agencies (24 in the greater metropolitan area)

agencies.¹ The environmental-review process provides an important means through which various stakeholders become involved in planning. Stakeholder involvement typically includes the ability to review and comment on project proposals but occasionally may lead to citizen-action lawsuits based on a variety of substantive or procedural claims associated with the project.

¹ Note that this responsibility is often shared with, or delegated to, the relevant state, regional, or local agency for a given project.

State-Level Actors

At the state level in California, roles and responsibilities for transportation planning are divided among several entities. The state legislature appropriates money to fund transportation projects and programs and delegates authority to other state and regional agencies for selecting specific projects. Caltrans, part of BTHA, bears primary responsibility for planning, designing, building, operating, and maintaining the state and interstate highway systems and related capital-improvement projects in California. For projects involving highways or larger regional and local roads, Caltrans often serves as the appropriate lead agency according to NEPA and CEQA.² The California DMV, also part of BTHA, tests and licenses drivers, maintains driving records, and registers and issues titles to vehicles and vessels, among other things. CTC advises the state on transportation projects and is responsible for allocating state and federal funds to projects throughout the state according to STIP, which is under CTC's authority. EPA delegates authority to ARB to regulate on-road mobile-source emissions—that is, emissions from cars and trucks—as described in CAA and its amendments.

Regional (Intercounty) Actors

For greater clarity, we find it useful to differentiate among regional agencies according to intercounty, county, and intracounty levels of jurisdictional authority. At the intercounty level, SCAG serves as the metropolitan planning organization (MPO) for L.A. County and for Imperial, Orange, Riverside, San Bernardino, and Ventura counties. MPOs are federally required planning bodies that serve each urbanized area with a population in excess of 50,000. MPOs outline transportation priorities in their 20-year regional transportation plans.

² CEQA is sometimes described as a little NEPA. CEQA and NEPA processes are similar and often overlapping. Importantly, both are required in California in order for federally funded transportation projects to be built, and both serve as a means for stakeholders to become involved in, and sometimes impede, the delivery of projects.

AQMD, while responsible mainly for regulating stationary-source emissions, also has responsibility for programs aimed at reducing vehicle trips and VMT in the South Coast Air Basin, a jurisdictional area roughly bounded by ocean and mountains surrounding the greater L.A. metropolitan region. This area includes portions of Los Angeles, Riverside, and San Bernardino counties and all of Orange County.

Regional (County-Level) Actors

At the county level, Metro serves as the RTPA. The role of an RTPA is to administer state funds and select projects for the Regional Transportation Improvement Program components of STIP. While MPOs and RTPAs in other regions of California are often one and the same, the L.A. region is an exception. Each of the counties represented by SCAG (the MPO) retains its own RTPA, and Metro fulfills this role for L.A. County. In addition to its planning responsibilities, Metro also operates bus and rail transit systems and funds 16 municipal bus operators, bikeways and pedestrian facilities, local roads and highway improvements, goods-movement projects, and FSP and call-box programs throughout the region. A 13-member board of directors governs Metro; members are the five L.A. County supervisors, the mayor of Los Angeles, three L.A. mayor-appointed members, four city-council members representing the other 87 cities in L.A. County, and one non-voting member who is appointed by the governor of California.

L.A. County agencies, such as LACDPW, also play an important role in providing transportation infrastructure in the county, especially in unincorporated areas. The five elected county supervisors, each of whom holds a seat on the Metro board, wield considerable political influence over transportation policy in Los Angeles.

Regional (Intracounty) Actors

In the county, cities and communities often organize themselves as COGs that seek to coordinate action on policies and programs

of regional significance. There are several COGs in L.A. County. SGVCOG includes 31 incorporated cities along with communities in several unincorporated areas, GCCOG includes 28 incorporated cities in southeast L.A. County, and SBCCOG has 16 member cities. Finally, WCCOG includes five member cities: Beverly Hills, Culver City, Santa Monica, West Hollywood, and Los Angeles.

Another example of a regional entity at the subcounty level is ACTA, which oversees construction in a 20-mile corridor connecting the Ports of Los Angeles and Long Beach with downtown Los Angeles. Formed as a joint-power authority involving the cities and ports of Long Beach and Los Angeles, ACTA's seven-member governing board includes two representatives from each port, a member of each city council, and a representative of Metro.

Local-Level Actors

At the local level, we differentiate among cities and neighborhood communities, each of which is capable of political organization and contributing to formal transportation decisions.

In L.A. County, there are 88 incorporated cities, the largest of which is the city of Los Angeles (Los Angeles County, undated). Relevant actors in each city include elected city-council members and mayors as well as administrative departments that play some role in transportation planning (such as transportation, planning, and public works). Owing to its much larger geographic area and population, as well as its connection to other cities, the city of Los Angeles occupies a prominent political position in the region. LADOT plans and funds major transportation improvements on freeways, rail lines, city streets, transit stations, parking garages, and bicycle and pedestrian facilities. LADOT also manages bus lines—such as DASH, Commuter Express, and Cityride—and more than 100 off-street parking facilities. LADOT regulates taxicab franchises and medical-transportation companies and enforces on-street-parking regulations. LADOT is responsible for an array of efforts to ensure the safety of motorists, pedestrians, and bicyclists, to facilitate the flow of traffic along major city streets

and calm traffic in residential neighborhoods, and to mitigate the traffic and parking impacts associated with new developments and special events in the city. The success of these efforts often depends on communication and sharing responsibility with other cities in the county.

In addition to the 88 cities, at least 196 discernible communities in L.A. County are capable of political organization (NACo, 2007). In the city of Los Angeles, many of these communities have formed neighborhood councils—community groups with self-appointed leaders intended to represent the unique interests of their neighborhoods. Neighborhood councils are similar to homeowners' associations except that the City of Los Angeles Department of Neighborhood Empowerment has certified them. It is important to note that neighborhood councils have no fiscal resources and cannot challenge the City in court (as homeowners' associations can do), because certified neighborhood councils are a formal component of city government. The Department of Neighborhood Empowerment (2008) currently reports the existence of 86 certified neighborhood councils in the city of Los Angeles, two more with certifications pending, and eight that are still forming. While neighborhood councils have only an advisory role in city government, their apparent influence on decisionmaking in Los Angeles has emerged in a growing number of cases since the program was initiated in 1999.³

³ Waldie (2007a, 2007b) attributed the denial of a building permit for a Kmart to the efforts of the Sunland-Tujunga Neighborhood Council, for example. Waldie also recalled neighborhood councils' successful pushback against proposed utility-rate hikes in Los Angeles and growing recognition and support of neighborhood-council efforts by selected council members. See also Orlov and Barrett (2005).

Theoretical Insights on Political Consensus Building

The challenges of planning in a political environment characterized by numerous interacting agencies and stakeholders with often-competing issues and agendas are unique neither to transportation nor to Los Angeles; indeed, understanding the factors that support successful collective action in the face of such obstacles has been of central interest to political scientists and planning theorists for decades. In this appendix, we review relevant theory from the planning and political-science literatures to distill key insights that may bolster efforts to build political consensus around promising strategies for reducing congestion in Los Angeles. These inform the analysis presented in Chapter Seven.

We begin by observing that congestion represents a “tragedy of the commons” problem (Hardin, 1968) and thus requires collective action to resolve. Failure to adequately address the requirements of collective action in a heterogeneous and democratically empowered society—and, in particular, to address concerns related to equity—helps to explain the decline of the rational-comprehensive planning model, an approach often applied to transportation in earlier decades (Black, 1990). More-recent research on policy implementation—grounded in system theory, principles of organizational behavior, individual strategizing theory, and communicative action—leads us to the ACF (Sabatier and Jenkins-Smith, 1988; Sabatier and Weible, 2007) and planning through consensus building (Innes, 1996). These two theories explicitly address the need for collective action and thus suggest means for successful consensus building. We briefly review each of these theoretical frameworks and illustrate their utility by examining

past examples of transportation planning in Los Angeles. Based on our review of these frameworks, we can enumerate general guidelines for fostering collective action in transportation and other domains.

The Tragedy of the Commons and the Need for Collective Action

In his classic essay, Garrett Hardin (1968) used the example of an open pasture shared by local herders to illustrate the “tragedy of the commons.” Each herder seeks to “maximize his gain” (Hardin, 1968, p. 1244) by increasing herd size and grazing time, even though doing so ultimately degrades the pasture for all. Traffic congestion, too, is a tragedy of the commons: Travelers use publicly available roads to pursue their various interests, but each traveler added to the road network degrades the level of service for all.

The tragedy of the commons is a recurrent theme among political scientists who study the roles of institutions, political behavior, and policy implementation associated with providing public goods. The notion is that a finite, freely available resource shares two important characteristics: the difficulty of excluding users and the fact that use by one individual means that less will be available for others. Left untended, the inevitable effect is overuse of the resource. In Hardin’s (1968, p. 1244) words, “freedom in a commons brings ruin to all.”

The classic solution is to “enclose” the commons by one of several management approaches: privatization, paying for use, or regulation. Each of these provides a mechanism for controlling use of the resource, and many of the congestion-relief strategies reviewed as part of this study fall into one of these two latter categories of solutions (we do not entertain the idea of privatizing the entire road network in Los Angeles). An important overriding lesson from Hardin, however, is that pursuing only technical solutions to problems—without also considering matters of human values—is an exercise in futility. At the same time, forging the necessary agreement among competing interests to manage the commons—that is, fostering effective collective action—remains a formidable challenge.

The L.A. experience exemplifies the challenge of collective action. Giuliano, Hwang, and Wachs (1993) reviewed the effects of AQMD's Regulation XV, which required businesses to reduce vehicle trips (through ride-sharing goals) to limit air-pollution emissions. The study demonstrated that the regulation was, in fact, an effective means of achieving this end, as the program reduced vehicle trips. One might thus interpret AQMD Regulation XV as an effective regulatory-based solution for enclosing the commons—a commons, in this case, defined by the road network and the air basin that encompass Los Angeles.

Yet, Regulation XV was also described as a “new program imposed on an unenthusiastic clientele by a centralized regulatory organization” (Wachs and Giuliano, 1992, p. 427). In other words, the regulation was imposed from above without first achieving collective agreement from those subject to the rules. Moreover, Regulation XV applied to firms but not to other segments of society, so the commons was not even fully enclosed. Not surprisingly, these factors engendered resistance from the business community, and this resistance ultimately led to the repeal of Regulation XV in 1995 and subsequent replacement by AQMD Rule 2202—a rule that made participation in employer-based trip-reduction programs voluntary.

Not surprisingly, ride-sharing rates decreased under Rule 2202 (Snyder, 2007). Indeed, Hardin argues that policy relying on voluntary mechanisms alone cannot be expected to solve the tragedy of the commons. The Regulation XV/Rule 2202 experience in Southern California appears to support this claim. Instead, Hardin suggests that effectively enclosing the commons, through any available management approach, requires “mutual coercion, mutually agreed upon” (Hardin, 1968, p. 1247), and this can be achieved only through collective action. In other words, effective policy follows from collective agreement to enforce and abide by rules to manage the use of public resources.

Decline of the Rational-Comprehensive Planning Model

Successful collective action requires accommodating competing interests and views. Failure to achieve such accommodation helps to explain

the decline of the rational-comprehensive model of planning in the United States since the 1960s.¹ According to the rational-comprehensive framework, decisionmakers first enumerate and rank values and objectives, then identify and evaluate policy options according to these values and objectives, and finally select and implement the policy that appears to perform best according to the evaluation (Lindblom, 1959; Lindblom and Braybrooke, 1963). Progressing in a logical sequence from problem to solution, the rational-comprehensive model is often described as *scientific planning*. The model implicitly assumes that cities are amenable to scientifically engineered improvement.

It is not surprising, then, that transportation planning—a field dominated by traffic engineers in the past several decades—traditionally assumed the rational-comprehensive mode of planning. Yet as the years progressed, this approach became increasingly prone to failure. Black (1990), for instance, cited the example of the Chicago Area Transportation Study of the late 1950s and early 1960s. In the study, planners successfully completed all of the steps of the rational-comprehensive process—all save implementation. The point of Black’s observation is that, while the rational-comprehensive approach appears to proceed in logical sequence from values and goals to comprehensive analysis to identifying the “optimal” solution, failure to account for the diversity of competing interests and opposing perspectives from the outset often dooms the entire process. From the 1960s forward, as social and environmental awareness and citizen involvement in planning has grown, evidence suggests that failure at the implementation stage may be more the norm than the exception with rational-comprehensive planning.²

Critics of the rational-comprehensive model have identified several crucial limitations of the approach (see Lindblom, 1959; Lindblom and Braybrooke, 1963; Altshuler, 1965a, 1965b; and Brooks, 2002). Chief among these is that rational-comprehensive planning does not

¹ See Friedmann (1987) and Brooks (2002) for useful typologies of planning and its historical development.

² See Altshuler and Luberoff (2003) for a historic review of urban politics surrounding investment in large-scale public projects (including transportation projects) and related social upheavals since the 1960s.

fully accommodate the diverse views of multiple stakeholders interacting in a democratic society and therefore fails to approximate the collective public interest in resulting plans.³ Whereas Hardin suggested that effective policy follows collaboration among stakeholders, Black suggested that, to foster successful collective action, planners and decisionmakers themselves must become involved with stakeholders on their issues of concern.

Collective Action and Equity in Transportation Planning

Competing views on equity emerge as a fundamental challenge in the pursuit of collective action in transportation planning. Also discussed under the rubric of social justice, equity is a concept that describes the fair treatment of groups and individuals in society. Most agree that this entails attention to human rights, the rule of law, and some form of a welfare safety net, although disagreement over important details has fueled debate for centuries among philosophers, planners, and elected leaders. While equity concerns are not solely a function of the transportation system, neither can transportation planning be isolated from the need to address equity issues (Deka, 2004). It is therefore useful to highlight two of the more challenging equity issues that will need addressing in order to implement many of the congestion-reduction and revenue strategies recommended in this book.⁴

The first concern relates to the relative distribution of costs and benefits among lower-income, minority, and other disadvantaged groups (Deka, 2004). Projects or policies under which the costs will fall more heavily on disadvantaged groups or the benefits will accrue primarily to more-advantaged members of society will raise legitimate

³ Indeed Black (1990, p. 36) concluded that it is

easier to carry out the rational planning process if the planning agency is autonomous and free from political interference. But if planners want to affect decisions, they may have to get involved in politics and sacrifice rationality to some degree.

⁴ For further discussion of equity issues in transportation, see Barr (1998), Deka (2004), and Taylor (2004).

equity issues, and such concerns can undermine the political or legal feasibility of the intended action.⁵ In the context of this study, several of the strategy recommendations—including cordon tolls, performance curb parking, and local fuel taxes—will likely face this issue, but there are at least two ways to mitigate the resulting equity concerns. First, to offset the concern, additional measures can complement strategies that create equity challenges. For instance, cordon tolls can be implemented in concert with significant improvements to the speed and efficiency of the transit system, which is patronized much more heavily by lower-income and other underrepresented riders. Second, for strategies that raise revenue, a significant portion of the revenue can be used to benefit disadvantaged groups. The revenue from cordon tolls, for instance, can be used to subsidize life-line toll rates for lower-income drivers as well as transit improvements for those who do not drive.

The second important issue involves the alignment of costs and benefits. Specifically, those who shoulder the cost of a transportation program may view it as unfair if they do not also reap a significant share of the benefits. A special case of this issue arises with the geographic distribution of costs and benefits (Taylor, 2004), and this is especially relevant for the idea of a countywide or regional fuel tax. If the revenues from such a tax were intended primarily to fund better transit options in the urban areas of Los Angeles, residents in the less densely populated suburban and exurban areas of the region would be unlikely to support such a measure, viewing it as spatially inequitable. In short, to enhance the chances of successful collective agreement, careful attention should be devoted to ensure that the costs of any proposed program are at least roughly aligned with the benefits.

⁵ In the mid-1990s, for example, BRU and the Labor/Community Strategy Center successfully sued Metro under CRA; their argument was that the agency's emphasis on funding rail-transit projects, which benefited primarily wealthier, suburban residents, effectively discriminated against bus riders, who were more likely to be from lower-income and other underrepresented groups. The lawsuit was ultimately settled in 1996 with a consent decree under which Metro agreed to reduce overcrowding on buses, lower transit fares, and take other steps to enhance countywide mobility (Garcia and Rubin, 2004).

Fostering Successful Collective Action

In the preceding passages, we have outlined some of the challenges that confront effective transportation planning in Los Angeles. These include the underlying complexity of the political environment, the need to engage multiple stakeholder groups—often with competing issues and agendas—in collective decisions, and the need to address equity issues that commonly arise with transportation plans and policies. We now shift the discussion to the development of strategies for overcoming these challenges. Based on a thorough review of the planning and political-science literatures, the ACF and planning by consensus building emerge as two prominent theories that offer valuable guidance on some of the key steps needed to foster the successful collective action that our recommendations will require.

The Advocacy-Coalition Framework

The ACF is a political, theoretical framework that describes the actions and conditions that drive policy change (Sabatier and Jenkins-Smith, 1988; Sabatier and Weible, 2007). The basic idea of the ACF is that stakeholders tend to form *advocacy coalitions*—alliances among groups with similar values or policy views—that interact with one another in a political contracting process to implement policy. The ACF assumes that participants in the policymaking process are rationally motivated but limited by imperfect information. Accordingly, they will rely on their *belief systems* to filter perceptions of the world around them and to fill in any gaps in available information. The ACF assumes that individuals' policy-belief systems are structured with multiple levels, ranging from deeper, core-value beliefs (such as the importance of collective versus individual rights) to shallower, secondary policy beliefs (such as views on the utility of transit investments). While individuals are unlikely to shift their core-value beliefs, the provision of information and other influences can lead individuals to change their minds about the benefits of one policy option or another. The ACF postulates three specific mechanisms that can lead to policy change:

1. *Hurting stalemates.* The mechanism of a hurting stalemate is that a given situation has become so unbearable for all advocacy coalitions that they become willing to work together to change the situation; unbearable traffic congestion could potentially qualify as a hurting stalemate that would motivate collective action.
2. *External shocks.* External shocks describe events outside of the immediate policy context that stimulate policy changes. These might include large socioeconomic shifts, changes in public opinion or in government, or outcomes from other policy arenas. For instance, the passage of ISTEA (P.L. 102-240) at the federal level, which tied the CAA-conformance requirements to transportation decisionmaking, is an example of an external shock that led to profound shifts in state and local transportation policy.⁶
3. *Accumulation of information.* Given new and trusted information, the ACF predicts that individuals are more likely to give up their secondary policy beliefs; over time, learning occurs and policies change. Without information, on the other hand, or given information with high uncertainty, individuals retreat into positions dominated by their deep core beliefs, leading to policy gridlock. By itself, the accumulation of information (and the associated learning) takes time, resulting in gradual policy changes; in combination with the other mechanisms described here, information can contribute to accelerated change.

The 1984 Summer Olympic experience in Los Angeles is an example of effective transportation planning that illustrates key features of the ACF. A study by Giuliano (1988) investigated several aspects of nonspectator travel behavior and institutional conditions associated with the Olympics, which could be viewed in the ACF context as an external shock. Giuliano noted that the effective management of traffic

⁶ Shrouds (1995, p. 193) argued that CAA may be “the most powerful of all environmental laws affecting transportation decisionmaking not only to achieve air quality goals but also to affect broader environmental goals related to land use, travel mode choice, and reductions in vehicle-miles traveled.”

during the event was not a result of unique transportation-management solutions, but rather the result of a unique decisionmaking environment. The consequences of no action were clear, and, therefore, leaders were prepared to act. Faced with the possibility of severe congestion in such a high-profile event, the mechanism of a hurting stalemate came into effect. Leaders representing state and local transportation departments, police departments, and regional transit operators voluntarily organized the L.A. Olympic Transportation Advisory Group. A constructive atmosphere emerged, in which “everyday conflicts between local agencies were forgotten, and all efforts were directed toward making the Olympics work” (Giuliano, 1988, p. 158).

These observations suggest that collective action among leaders in Los Angeles is, in fact, possible. Giuliano reported further that conditions for success included a clearly defined problem,⁷ well-informed and agreed-on means to address the problem,⁸ and a willingness to consider and apply any technically feasible strategy, if only for a limited time. Giuliano also concluded that the success in changing nonwork travel behavior, however brief, traced to a substantial public-information campaign. That is, the three ACF policy mechanisms—the influence of information, the external shock of the Olympics, and the collective agreement that severe congestion represented an unacceptable hurting stalemate—generally explain the success of the Olympic program in reducing traffic congestion.

It is important to note, however, that the effectiveness of the policies implemented during the Olympics was short-lived.

Over the two-week Olympics period, traffic conditions shifted from extremely light during the first few days, to normal conditions by the last few days, suggesting that once it became clear that gridlock conditions would not materialize, there was [no]

⁷ During the 1984 Olympics, relatively accurate forecasts of Olympic activities were available. Therefore, the timing, location, and magnitude of travel demand could be estimated.

⁸ As in our study, major capital investments in transportation infrastructure were deemed infeasible, so traffic was to be accommodated in the existing system by other means. Demand-management strategies employed during the Olympic program were known to be effective based on experiences elsewhere.

longer any incentive to make changes in travel behavior. (Giuliano, 1988, p. 156)

If we are interested in designing political strategies that remain effective for the longer term, we must look further for guidance.

Planning Through Consensus Building

Planning through consensus building (Innes, 1996) is a communicative theory of planning that assumes that the capacity to act depends on the free exchange of beliefs and intentions in open, deliberative forums. Effective planning thus becomes an exercise in effective communication, which, in turn, facilitates agreements that approximate the public interest. Forrester (1980) listed four basic requirements for effective communication in the planning context: comprehensibility, sincerity, legitimacy, and truthfulness. Meeting these requirements in an open dialogue among stakeholders, according to the theory, facilitates mutual trust and deeper understanding among participants regarding the issues at hand (including social-justice issues). This ultimately leads to more-effective planning outcomes.

Another important requirement for effective communication is the mediation of political power (Forrester, 1989; Flybjerg, 1998) to ensure that the communicative process is not distorted and participants are not excluded. In plainer terms, all concerned stakeholders—powerful or not—must be included in the planning dialogue in a meaningful way. Failure to meet these fundamental requirements is purported to fuel distrust among participants and ultimately lead to collapse of the planning process (that is, implementation will fail to occur).

The I-710 major-corridor study (MCS) in Los Angeles, reviewed by Chaves, Garcia, and Gilmore (2006), serves as an example of successful consensus building in transportation planning. The intent of the MCS, initiated in 2001, was to “analyze the traffic congestion, safety, and mobility problems along the I-710 travel corridor and to develop transportation solutions to address these problems as well as some of the quality of life concerns experienced in the I-710 Corridor” (Parsons Brinckerhoff, 2004, cited in Chaves, Garcia, and Gilmore, 2006, p. 78). The study initially proceeded largely as a technical exercise

managed by Metro, GCCOG, and Caltrans. While the effort included large oversight and technical-advisory committees (comprising representatives of 14 corridor cities, the county, the Ports of Los Angeles and Long Beach, FHWA, FTA, AQMD, Caltrans, and CHP, as well as various technical experts), the initial effort did not sufficiently involve members of the affected communities—especially local residents and businesses—in the design and selection of alternatives. Following substantial community-group resistance to the initial plan, Metro's board voted 10-0 in May 2003 to abandon all construction designs proposed in the \$3.9 million study. Note the resemblance to the failed Chicago Area Transportation Study of the 1950s and 1960s, discussed earlier.

Interpreted through the lens of communicative-planning theory, the initial planning effort lacked sufficient legitimacy, given that the groups most affected by problems related to the I-710 corridor (such as safety issues, poor air quality, and congestion) were not appropriately involved in generating ideas and recommending solutions. This was corrected in July 2003 when Metro established a two-tiered community-participation structure involving the support of planning, facilitation, and engineering firms to (1) offer independent expertise on matters of health and air quality, economic development, and environmental justice (the tier 1 community advisory committee, or CAC) and (2) ensure greater community-level participation in the process (the tier 2 CAC). Working together with a technical-advisory committee and an oversight policy committee, the tier 1 and 2 CACs helped to develop and present a locally preferred strategy and associated recommendations to Metro. In January 2005, the Metro board adopted a final report based on these recommendations, thus concluding the study.

From this example, we see that the more-extensive community-involvement approach not only arrived at a different strategy but actually reframed the problem in decisionmakers' minds—from a problem of congestion and mobility to one with greater appreciation of community-level concerns for air quality and public health. More-effective communication with stakeholders thus allowed decisionmakers to better approximate the public interest. Likewise, community-level stakeholders realized through the extended process that, whatever the overriding concern (congestion or air quality), "some-

thing must be done to address current congestion and design on the I-710” and that this aim would be best served by allowing the project to proceed (Chaves, Garcia, and Gilmore, 2006, p. 82). Thus, transportation planning in Los Angeles can be successful when it is comprehensible, sincere, legitimate, and true to all interests involved. Ensuring these conditions may require substantial community outreach as well as compromise on certain technical objectives.

Guiding Principles for Fostering Successful Collective Action

Our discussion of the political complexities of transportation planning and the theories of successful collective action suggest several general principles that should prove helpful (and possibly essential) in efforts to implement some of the more promising but controversial congestion-reduction and revenue strategies recommended in this book. In this section, we introduce these principles; in the next, we employ them to develop specific political recommendations for transportation decision-making in Los Angeles.

Strong and Persistent Political Leadership

To develop and implement a potentially controversial transportation project or program, it is important to enlist a political champion to galvanize and marshal support. The political champion might be an elected official, civil servant, or judge, for example, or one or more committees with broad agency or community representation might serve the function.⁹ A key requirement is that the political champion must be viewed as legitimate, gaining the trust of the various stakeholders involved in decisionmaking and maintaining open dialogue as implementation proceeds. Furthermore, to foster longer-term solutions, the leadership must persist over the longer term as well. The

⁹ Examples of the leadership-by-committee approach include the Los Angeles Olympic Transportation Advisory Group and the various agency and community-level committees involved in the I-710 MCS.

political champion—whether individual or group—should be able to transcend political term limits such that neither the authority nor the political momentum required to implement effective congestion-reduction and revenue strategies is interrupted. Such persistence and patience will be especially key for various forms of congestion pricing. Short (2004) reported that initial popular support for the pricing schemes in London, Rome, Singapore, and Norwegian cities rarely exceeded 50 percent. Yet the support for this approach increased over time as the benefits became clear with implementation.

Effective Communication Among Agencies and Stakeholder Groups

Related to the first principle, issues and concerns of agencies and stakeholders should be heard in advance of any formal proposal. Early communication and consultation helps to create an atmosphere of trust and sincerity among participants, providing the opportunity for decision-makers to become familiar with the various issues and concerns of different groups from the start. As demonstrated in the I-710 MCS, this can help to avoid costly and possibly irrelevant technical work. Early outreach also provides an opportunity to educate stakeholders on complex problems and explore possibilities for compromise on multiple, competing goals. Finally, ongoing communication with stakeholder groups, especially during early phases of implementation, serves to prepare the public (thus avoiding uncertainty and surprise) and provides means to discuss minor modifications before major problems occur. Indeed, much of the success in the Olympic experience traced to a substantial public-information campaign (Giuliano, 1988).

Sufficient Agreement on the Problem

It is also key to develop sufficient agreement among stakeholders that traffic congestion in Los Angeles is unacceptable. Such agreement would correspond to the ACF notion of a hurting stalemate, one of the factors that can prompt policy change. Note that the agreement need not be universal; in fact, the I-710 experience suggests that getting all stakeholders to concur with specific project objectives may never occur. Yet building agreement among a majority of stakeholders that “something has to be done” may be enough to restart a stalled process.

Credible Underlying Research and Analysis

The ACF predicts that information can lead to policy change, alone or in combination with other mechanisms. The ability of information to effect change depends, however, on its credibility in the view of stakeholders. Certain analytical and modeling work requires experts, but experts should not always be left alone to conduct their work in a vacuum. Models, according to Klosterman (2007), require analysts and decisionmakers to be clear and upfront about their values, choices, and assumptions—including the treatment of social-justice issues. Yet analysts and decisionmakers are no more experts on these matters than the community members are whom they intend to represent. Sophisticated analysis will thus be viewed as more credible when stakeholders are able to help shape the inputs, not just review the outputs. This implies that one of the more valuable roles for models lies in the ability to help construct a range of meaningful scenarios, identify outcomes, and evaluate impacts (Deal and Pallathucheril, 2007). This can inform discussions among stakeholders and help to construct a community narrative that supports a consensus decision on appropriate congestion-reduction strategies. The I-710 MCS experience, for example, clearly demonstrates the importance of involving community-level stakeholders in the design and evaluation of alternatives from the outset, rather than leaving the task solely to the project technical team.

Equitable Allocation of Costs and Benefits

For a transportation measure (or package of measures) to be viewed as fair and earn broad support from different constituencies, those who shoulder the costs should also reap a significant share of the benefits. At the same time, the mitigation of social-justice issues will require that lower-income and other disadvantaged groups not face costs beyond their ability to pay, even if some individuals from those groups will reap considerable benefits from the program. Striking a balance between these two competing equity objectives will be a significant challenge, especially in the case of congestion pricing and revenue recommendations. A two-pronged strategy may be needed: first, ensuring that the benefits are distributed in rough proportion to the costs, and second, subsidizing the costs (or providing options, such as improved transit,

through which travelers can avoid paying higher costs to drive) to mitigate social-justice concerns.

Motivated Supporters and Conflict Resolution

Our legal framework and democratic institutions have been structured such that small but vocal opponents can often halt a project that otherwise enjoys broad support. A potential counterbalance to this dilemma is enrolling equally vocal support among groups motivated to see that a program succeeds and constructively moderating this deliberation. Allocating revenues may be key in this regard and, in fact, may convert detractors into enthusiastic proponents. Shoup (2005), for example, describes the case in which returning a share of parking-meter revenues to local merchants created a powerful constituency in support of variable curb-parking rates. Following similar logic, King, Manville, and Shoup (2007) argued that cities could provide political support for congestion pricing on freeways if the resulting revenues were returned to the municipalities through which the freeways run. Cities are “well organized and large enough to be powerful, but small enough to engineer consensus among their constituents about how to spend the money” (King, Manville, and Shoup, 2007, p. 122).

Consistent Enforcement

Our final principle concerns the importance of enforcement. Short (2004, p. 3), reviewing recent pricing schemes, observed that, “if a weakness exists in the enforcement, it will be found. Those who pay need to know that those who don’t will be punished.” This guidance echoes Hardin’s lessons. Whatever the strategy used to address Los Angeles’s growing congestion problem, one must not forget the problem’s fundamental nature as a tragedy of the commons. Conscience cannot be relied on to effectively manage the commons, and enlarging the commons (building more roads) is, for a variety of reasons, not a reasonable option. Instead, reducing congestion in Los Angeles will require enclosing the commons, and political strategies to this end must forge collective will toward “mutual coercion, mutually agreed” (Hardin, 1968, p. 1244).

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