EFFECTIVE PRACTICES FOR CONGESTION MANAGEMENT: FINAL REPORT

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Prepared by:
Cambridge Systematics, Inc.
Cambridge, MA

Resource Systems Group, Inc.
Burlington, VT

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1.0 Introduction

The objective of this research is to develop a succinct review of current knowledge and thinking about the relationship among transportation congestion, economic activity, economic growth, and transportation system investment at regional and national levels, and about strategies for reducing congestion, that can be posed as models for wide adoption in metropolitan areas.

Traffic congestion is in part a by-product of a growing population and thriving economy. If current trends continue, we can expect that the extent and duration of congestion will increase and affect more communities. States and metropolitan communities must have the resources and flexibility to consider, implement, and manage a portfolio of cost-effective investment strategies to deliver enhanced system performance, reliability, and redundancy for a growing economy and population.

This research documented in this report consists of the following elements:

- A review and synthesis of recent research on congestion and its relation to economic activity and economic growth at regional and national levels;
- A review of congestion mitigation strategies that have been applied in metropolitan regions and evaluation of their effectiveness in reducing congestion;
- Case studies of effective congestion management practices in four metropolitan areas; and
- A review of lessons learned regarding the implementation of effective congestion management practices.

Section 2.0 finds that well functioning transportation systems play an important role in the economy – supporting the movement of goods as well as people. While congestion is in some ways a reflection of a thriving economy, excessive congestion also reduces mobility and accessibility and increasing costs to businesses, affecting economic competitiveness. This is true both at a regional scale, where businesses may look to locate or expand elsewhere if congestion is too severe; and at a national scale, where highway, rail, and port congestion can make U.S. goods and services less competitive on the global market.

Section 3.0 finds that there are a wide range of congestion management strategies that have been applied – with a similarly wide range of effectiveness and costs. Physical capacity expansion projects can have significant congestion reduction benefits but also significant costs and other impacts. Operational strategies to keep traffic flowing more efficiently have, in many cases, the opportunity for significant benefits at much lower costs; but implementation is sometimes hampered by issues related to institutional capacity and coordination, funding, and political acceptance. Most demand management strategies to reduce travel have generally had limited effectiveness in the U.S., although opportunities for these strategies are increasing as consumers respond to high fuel prices and climate change becomes a high-profile issue.

Section 4.0 summarizes case studies of congestion management practices in four metropolitan areas: Dallas-Fort Worth, Texas; Minneapolis-St. Paul, Minnesota; Orlando, Florida; and San Diego, California. The detailed case studies are included as Appendices to this report. These areas were selected as having "leading-edge" congestion management practices that effectively support congestion reduction. The objective of the case studies was to document these areas' activities in more depth, by conducting site visits and telephone interviews with local agencies to discuss activities, success factors, and lessons learned. The case studies find that effective congestion management is based on a variety of operations and management strategies, such as incident management, arterial management, and demand management, in addition to traditional capacity expansion. Furthermore, it includes not just technical strategies but also strong working partnerships amongst stakeholders; sound data to support strategy analysis and evaluation; and good communication with the public to build support for implementation.

Section 5.0 documents lessons learned regarding the effective implementation of congestion management, based on the case studies as well as other recent reviews of effective practice. Examples exist throughout the country of state and metropolitan agencies working together to identify congestion problems, identify effective strategies, implement strategies, and measure their impacts. While many good examples exist of particular elements of congestion management, there are fewer examples of truly "holistic" approaches representing effective practices along all of these dimensions. Furthermore, many of the most effective congestion management strategies require difficult tradeoffs – whether it means locating funding, mitigating environmental impacts, or overcoming public acceptance related to a specific bottleneck improvement or pricing proposal.

Because of the multitude of factors that affect metropolitan congestion, it is difficult to make clear statements about which areas have been most effective in managing congestion. Some areas have been successful in implementing capacity expansion projects – whether publicly or privately funded – while others have turned to operational and demand management strategies in the face of severe constraints on expanding capacity. Nevertheless, this review suggests that there are many more things that could be done to reduce congestion, even in the face of limited funding. Accomplishing these actions requires strong coordination amongst multiple agencies and stakeholders, sound data and technical analysis methods, and effective methods for communicating the benefits of specific strategies to the general public.

2.0 Relationship Between Congestion and Economic Growth

2.1 Overview

The objective of this section is to synthesize the most relevant research on transportation congestion and its relation to economic activity and growth. This section reports findings from existing research undertaken for the U.S. Department of Transportation (DOT), the U.S. Chamber of Commerce, American Association of State Highway and Transportation Officials (AASHTO), regional agencies, and others on the impacts of congestion on the economy.

Key findings of this review are:

- Metropolitan congestion has been increasing in recent years and is projected to continue to increase. While traffic growth is slowing compared to past trends, growth will continue in both passenger vehicle and truck vehicle-miles of travel (VMT), as a result of population increases, economic expansion, and changes in travel and production patterns. This growth will continue to outstrip growth in roadway capacity.
- Studies of the impacts of congestion have found that businesses adapt to increasing congestion, but that these adaptations incur costs. Congestion results in direct costs to shippers due to increased travel-time and vehicle operating costs, as well as indirect costs through reduced accessibility to labor, customer, and supplier markets. The end result is that goods and services are more expensive, and economic productivity is reduced.
- About half of all congestion is "nonrecurring" – resulting from incidents, bad weather, work zones, or special events. Research has shown that travel-time reliability is valued at a significant premium by users, meaning that nonrecurring congestion results in disproportionately high economic costs.
- Congestion may affect U.S. competitiveness in the global economy by increasing the costs of domestically produced goods and services. The margin of U.S. competitive advantage is shrinking in key sectors of the economy and a reliable transportation system is critical to maintaining this margin. Costs are increased not only by highway congestion but also by congestion on the nation's railways and at international ports.
- High levels of congestion can impact the competitiveness of individual regions by making the region a less attractive place to live or locate a business.

- Research suggests that the annual costs of congestion may run into the low billions in large metropolitan areas. Direct costs alone (travel-time and vehicle operating costs) may be in the range of $30 to $80 billion on a nationwide basis, with significant additional indirect costs.
- Studies to model the benefits of both highway and transit investment programs to relieve congestion in specific regions have found favorable cost-benefit ratios as well as measurable increases in regional economic output.
- While truck traffic represents only 5 percent of total vehicle miles, the freight sector experiences about 27 percent of congestion costs. Strategies that focus on routes heavily used by freight traffic will therefore have disproportionate benefits.

The remainder of this section is organized as follows:

- Section 2.2 discusses transportation's benefits to the economy, and how those benefits can be measured;
- Section 2.3 defines congestion and discusses its sources and types;
- Section 2.4 presents recent trends and future projections for highway congestion nationwide;
- Section 2.5 discusses the nature of congestion's impacts on economic activity and growth;
- Section 2.6 presents findings from specific national and regional studies of congestion's economic impacts; and
- Section 2.7 discusses the implications of rising fuel prices for the conclusions drawn in this section.

2.2 Transportation's Benefits to the Economy

Transportation's Role in the Economy

Understanding how transportation contributes to the overall economy is the first step in understanding how congestion and other transportation problems can hurt economic growth and competitiveness.

The transportation sector represents a significant amount of direct economic activity. In 2002, transportation-related goods and services accounted for more than 10 percent – over $1 trillion – of U.S. Gross Domestic Product (GDP). More fundamentally, however, transportation is a basic enabler of economic activity. Growth in productivity is the fundamental driving force for economic growth, and productivity growth in freight transportation has long been a driving force for the growth of overall U.S. productivity, contributing directly to the growth of the U.S. GDP. For example, from 1991 to 2000 labor productivity rose 21 percent in the overall nonfarm business sector. During the same time period, labor productivity rose 23 percent for trucking and even more for the rail and pipeline modes. Such productivity gains result in lower transportation costs, bringing savings to consumers and reducing business costs. (BTS, undated)

The Economic Benefits of Transportation Improvements

Highway congestion is one factor that affects the productivity of trucking and therefore of freight movement as a whole. To the extent that transportation improvements reduce congestion, they improve transportation productivity by reducing shipping costs and enhancing accessibility to labor, customer, and supplier markets. Measures that reduce congestion have effects similar to transportation projects such as new or improved highways or transit that open up new markets, reduce travel times between points, and otherwise improve accessibility.

The direct economic benefits of transportation improvements to transportation system users can be measured by the time and cost savings resulting from an improvement, and knowing what value typical travelers (passenger or freight) place on their time. For example, shippers must pay truck drivers a certain hourly wage (including benefits). Travel time for "on-the-clock" travelers also is a direct cost to businesses, based on the employee's wage rate. The cost of travel time for commuters also may be partially absorbed by businesses, if the labor market is tight and firms must compete for workers by raising wages. Fuel costs and vehicle wear and tear also tend to increase under congested conditions; improvements that save time reduce other costs for travelers and businesses as well.

In addition to these direct cost impacts, transportation improvements have a broader benefit to the economy by improving accessibility to specialized inputs. Improvements that reduce travel times or provide access to new areas can expand customer or supplier markets, expand labor markets, and reduce business operating costs through lower direct expenses or increased economies of business operation. Firms may be able to utilize labor that more specifically meets their production needs, as well as selling to a broader range of customers. They also may be able to achieve logistic and scheduling efficiencies as well as economies of scale. These impacts contribute to overall economic productivity.

Measuring Transportation's Benefits

The economic benefits of transportation improvements have been measured in a number of different ways. Some studies examine levels of investment or expansion of the transportation system, while others tie economic activity to travel-time or accessibility improvements.

Macroeconomic studies of productivity. One method of estimating transportation's impacts on the economy attempts to measure the national-level, productivity-enhancing benefits of transportation infrastructure using statistical modeling. Researchers such as Aschauer, Nadiri, Munnell, and Eddington have measured the relationship between infrastructure investment, especially highway capital, and industry productivity growth. While these studies do not directly assess the impacts of congestion, they do demonstrate that investments to improve travel conditions – through reducing travel times, providing access to larger areas, etc. – can have significant economic benefits.

The Eddington Study in the United Kingdom may be the most recent and single largest study ever undertaken on this topic. The study reports that on average a 10 percent increase in public capital infrastructure stock increases overall gross domestic product (GDP) by about 2 percent, and that a 5 percent reduction in travel time for all business travel could generate around 2.5 billion pounds of cost savings. Eddington also reviews the findings of previous studies. He concludes that although there is considerable variance in the empirical evidence, the studies are broadly consistent with the conclusion that a one per cent increase in public capital stock could result in a one-time, sustained increase in GDP of 0.2 percent for a developed economy. (Eddington 2006)

Relationship between transportation investment and job growth. A second set of studies has used statistical methods to examine the observed relationship between transportation investment and job and income growth in particular regions, while controlling for other factors that may affect growth. For example, extensive studies have been conducted of the Appalachian Highway Development System as well as various elements of the Interstate Highway System (c.f., EDRG/FHWA 2001). Like the macroeconomic productivity studies, these studies have focused on highway or other transportation investment and capacity as the explanatory variable, rather than travel-time savings, and therefore do not provide direct evidence on the benefits of congestion relief.

Direct and indirect user costs of congestion. Studies such as the Texas Transportation Institute's Mobility Monitoring Reports quantify the direct costs of congestion as a result of excess travel time, by assigning a value of time (which may differ by type of user) to measured delay. Some studies also have estimated indirect costs, including logistics costs to shippers. Results of these studies are summarized in Section 2.6.

Simulation models. Simply totaling the direct and indirect user costs of congestion does not measure the full impact of congestion on economic activity. Economic simulation models are sometimes used to assess the secondary and tertiary economic effects. These models assess the impact on gross regional product (GRP), personal income, jobs, and other measures of economic activity. Inputs to the regional simulation model include changes in business costs and/or productivity that result from the direct transportation user benefits of an improvement. Such models have been used to estimate the economic benefits of individual major transportation investments as well as regional or statewide investment programs. Examples of such studies in Chicago, Los Angeles, New York, Portland, and other cities are described in Section 2.6.

Observing congestion's impacts. The direct relationship between congestion and economic activity is difficult to observe in practice, which is why congestion's impacts are usually modeled instead. In part this is because congestion is a *result* of economic activity, and therefore, while excessive congestion represents a drain on businesses, it also indicates a high amount of economic activity in a particular area. If trends over time or across space are to be examined, higher amounts of congestion may well correlate with greater amounts of economic activity. Nevertheless, there is anecdotal evidence that if congestion becomes too great, growth in business activity in the affected region may be curtailed. For example, business groups are worried that the stalemate over taxes to fund transportation projects may doom future development projects in Northern Virginia.[1] Similarly, one of the nation's top site selection experts believes that Metro Atlanta's traffic congestion is endangering its future growth, and that some companies are rejecting Atlanta because of traffic.[2]

NCHRP Report 463, *Economic Implications of Congestion*, attempted to quantify congestion's impacts by conducting surveys of businesses and developing models to quantify their costs. The study went beyond user expense and travel-time costs to look at the full range of cost impacts to businesses. The researchers constructed statistical models for the Chicago and Philadelphia metropolitan areas to analyze the degree of sensitivity of various types of business activity to the costs of transporting products and worker commuting. Some of the findings of this study are discussed in Section 2.5.

Congestion has other impacts that may indirectly affect the economy, most of which are not accounted for in typical studies of economic impacts. Congestion increases fuel use, contributing to global climate change and to the costs of dependence on foreign oil. It also tends to increase air pollution, contributing to increased health care costs, lost worker productivity due to illness, and premature deaths. Finally, if congestion substantially reduces the quality of life in a region, it can reduce economic competitiveness by making the region less attractive to workers and businesses.

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[1] Bloomberg.com. "Virginians Spurn Taxes, Sit in Traffic as Road Gridlock Worsens." March 25, 2008.

[2] Atlanta Journal-Constitution. "Consultant: Atlanta's traffic is endangering its growth." December 17, 2007.

2.3 DEFINITION, SOURCES, AND TYPES OF CONGESTION[3]

Definition of Congestion

According to FHWA, congestion can be defined as "delay compared to the time it takes to make a trip under ideal conditions." Congestion is best measured based on **the travel time experienced by users of the highway system**, which is the most direct measure of how congestion affects users.

Highway congestion is caused when there are more vehicles than available space on the road, or, stated differently, when traffic demand approaches or exceeds the available capacity of the highway system. Traffic demands vary significantly depending on the season of the year, the day of the week, and even the time of day. Also, capacity can change because of weather, work zones, traffic incidents, or the mix of drivers and vehicles on the road.

Average or total delay for a facility, corridor, or region is one important measure of congestion. The **Travel-Time Index** is a basic measure of the total amount of congestion. It is the ratio of the peak-period travel time to the travel time under ideal conditions. A Travel-Time Index value of 2.3 indicates that peak-period travel takes 30 percent longer than under ideal conditions.

Travel-time reliability represents an additional important concept. Travel-time reliability can be defined in terms of how travel times vary over time (e.g., hour-to-hour, day-to-day). This concept of variability can be extended to any other travel time-based metrics such as average speeds and delay. Three basic measures of reliability have been developed:

- **Buffer Time** – The extra time (or time cushion) that travelers must add to their average travel time when planning trips to ensure on-time arrival (19 out of 20 times – i.e., the 95th percentile travel time);
- **Buffer Index –** The ratio of the Buffer Time to the average travel time; and
- **Planning-Time Index** – The ratio of the total trip time (average plus buffer) required to ensure on-time arrival, to the average trip time.

The concepts of average delay, Travel-Time Index, and Planning-Time Index are illustrated in Table 2.1, which shows these measures for the 10 most congested metropolitan areas (based on delay). Reliability data are only available for some cities and are based on only a few freeways, so the data are not necessarily comparable across urban areas.

[3] This section is adapted from: Traffic Congestion and Reliability: Trends and Advanced Strategies for Congestion Mitigation (FHWA 2005b).

Table 2.1 Measures of Congestion, 10 Most Congested Urban Areas

	Annual Delay per Traveler		Travel Time Index		Planning Time Index
Urban Area	2005 Hours	Rank	2005	Rank	2005
Los Angeles-Long Beach-Santa Ana, California	72	1	1.50	1	1.92
San Francisco-Oakland, California	60	2	1.41	3	1.51
Washington, D.C.-Virginia-Maryland	60	2	1.37	7	n/a
Atlanta, Georgia	60	2	1.34	11	n/a
Dallas-Fort Worth-Arlington, Texas	58	5	1.35	9	n/a
San Diego, California	57	6	1.40	4	1.66
Houston, Texas	56	7	1.36	8	2.01
San Jose, California	54	8	1.34	11	n/a
Orlando, Florida	54	8	1.30	17	n/a
Detroit, Michigan	54	8	1.29	21	1.65

Source: Texas Transportation Institute, 2007.

Sources and Types of Congestion

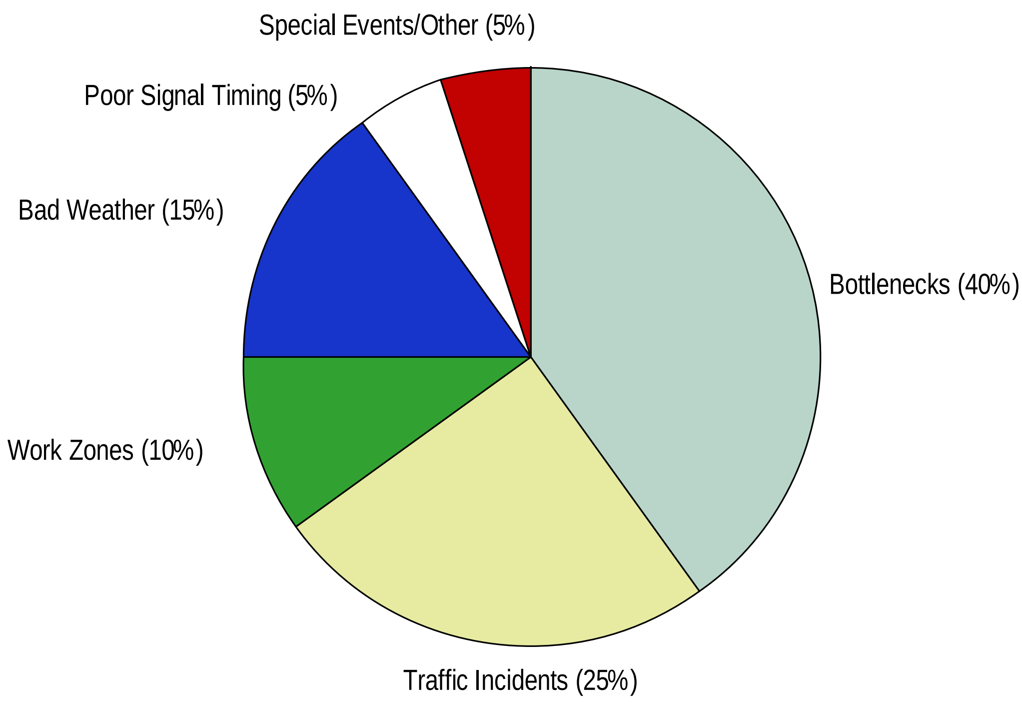
Previous work has shown that congestion is the result of seven factors, often interacting with one another.

- **Physical Bottlenecks ("Capacity")** – Capacity is the maximum amount of traffic capable of being handled by a given highway section. Capacity is determined by a number of variables, such as the number and width of lanes and shoulders, merge areas at interchanges, and roadway alignment (grades and curves).
- **Traffic Incidents** – Incidents can disrupt the normal flow of traffic, usually by physical impedance in the travel lanes. Events such as vehicular crashes, breakdowns, and debris in travel lanes are the most common form of incidents.
- **Work Zones** – Construction activities on the roadway can result in physical changes such as a reduction in the number or width of travel lanes, lane "shifts," lane diversions, reduction, or elimination of shoulders, and temporary roadway closures.
- **Weather** – Rain, snow, ice, fog, and flooding can lead to changes in driver behavior that affect traffic flow.

- **Traffic Control Devices** – Intermittent disruption of traffic flow by control devices such as railroad grade crossings and poorly timed signals contributes to congestion and travel-time variability.
- **Special Events** – Special events can create situations in which traffic flow in the vicinity of the event is radically different from typical patterns. Special events occasionally cause surges in traffic demand that overwhelm the system.
- **Fluctuations in Normal Traffic** – Day-to-day variability in demand leads to some days with higher traffic volumes than others. Varying demand volumes superimposed on a system with fixed capacity also results in variable (i.e., unreliable) travel times.

While local sources vary widely, FHWA has developed national estimates of the contribution of each source to overall congestion (Figure 2.1). Just under half of the congestion experienced in the U.S. happens virtually every day – it is "recurring" – primarily as a result of bottlenecks in the system, but also as a result of poor signal timing. The other half of congestion is caused by temporary disruptions that take away part of the roadway from use – or "nonrecurring" congestion. The three main causes of nonrecurring congestion are: incidents (25 percent of congestion), work zones (10 percent of congestion), and weather (15 percent of congestion), with special events and other causes also contributing.

Figure 2.1 Sources of Congestion



Source: FHWA (2005).

2.4 Congestion Trends and Projections

Recent Trends

Congestion is increasing in most U.S. metropolitan areas, as population and economic growth create travel demands that outpace investment in the transportation system.

- The Texas Transportation Institute (TTI), in its most recent annual urban mobility monitoring report (TTI 2007), reports that between 1982 and 2005, delay per traveler on the highway systems in America's larger cities has, on average, nearly tripled – increasing from 14 hours annually in 1982 to 38 hours in 2005. Congestion is estimated to waste 4.2 billion hours of time nationwide, at a cost (including time and wasted fuel) of $78 billion. The cost of delay and wasted fuel was $710 per traveler in 2005. These costs reflect only the direct travel-time costs (based on value of time), not secondary impacts to the economy.
- TTI also reports that travel between 1985 and 2005 increased 105 percent in large metropolitan regions while road capacity on freeways and major streets grew by only 45 percent. Travel by public transportation increased, 30 percent over this time period, not enough to offset the increases in overall travel. But public transportation still plays an important role in reducing congestion; if all transit users commuted by car, there would be an additional 493 million hours of delay nationwide.
- Free-flowing traffic is seen less than one-third of the time in urban areas over one million population; while congestion is worst in the largest metropolitan areas, it has been increasing in areas of all size.
- Reliability also is getting worse. In some metro areas, travelers and freight shippers need to plan on twice as much extra travel time if they have an important trip as they would allow in average conditions, considering the worst-case travel day of a typical month (95^{th} percentile travel time).

By comparing trends in congestion and highway investment across urban areas, TTI researchers have observed that additional roadways appear to reduce the rate of increase in congestion. Regions where road capacity has grown at about the same rate as travel demand have seen less delay growth than areas where travel demand has increased much more rapidly than road supply. On the other hand, the growth in facilities has to be at a rate slightly greater than travel growth in order to maintain constant travel times, if additional roads are the only solution used to address mobility concerns. This rate of investment was achieved by only 5 of 85 metropolitan areas studied. The authors therefore suggest that there must be a broader set of solutions applied to the problem than just highway capacity expansion.

Future Projections

Congestion on the nation's highways is expected to increase. In the 2007 National Cooperative Highway Research Program (NCHRP) study *Future Options for the National System of Interstate and Defense Highways*, researchers concluded that congestion on the Interstate system will increase substantially as long as past rates of traffic growth and lane-mile construction remain constant. GDP growth projected at three percent annually, combined with one percent annual population growth, is expected drive VMT growth at roughly two percent annually over the next 20 years. According to FHWA projections, without additional capacity, recurring peak-period congestion will occur on 40 percent of the National Highway System (NHS) in 2035, compared with 11 percent in 2002. This will slow traffic on nearly 20,000 miles of the NHS (versus 10,600 currently) and create stop-and-go conditions on an additional 45,000 miles (versus 6,700 currently). (U.S. DOT 2007a)

Growing freight transportation demand – the result of economic growth as well as changes in the structure of production systems – is a significant contributor to increasing congestion. The General Accountability Office (GAO 2008) reports that the tonnage of goods shipped by trucks is projected to increase by 98 percent by 2035, with other modes also showing substantial growth. The GAO finds that freight mobility is limited by inefficiencies in how infrastructure is used, such as poor road signal timing and prices paid by users that do not align with infrastructure costs, resulting in congestion. Furthermore, constrained freight mobility has adverse economic costs for consumers, shippers, and carriers, as well as in urban centers where congestion exacerbates environmental pollution and increases health risks, such as respiratory illnesses.

The forecasts cited here were generally developed prior to the most recent run-up in fuel prices, which first crossed the $3 per gallon threshold for gasoline in August 2005 and exceeded $4 per gallon in June 2008. If prices remain at or above this level, it is likely that the future increase in VMT will be somewhat lower than forecast. There already are indications of short-term decreases in VMT, with FHWA reporting that VMT in the first four months of 2008 was 2.1 percent lower than in the same period of 2007. Some experts are predicting that the rate of VMT increase will slow to roughly 1.4 percent annually over the next decades. VMT growth also may be affected if significant policy actions are taken to address climate change.

A Cambridge Systematics review of oil price forecasts conducted in June 2008 found that there is disagreement among economists over the likely future direction in oil and gasoline prices. In particular, it is not yet clear whether the current prices reflect a structural shift due to increases in worldwide demand without matching supply increases (in which case prices of $4 per gallon or higher would be sustained in the coming years) or a "bubble" fueled by commodity speculation, in which case gas prices could fall back into the range of $2 per gallon after the bubble pops.

2.5 CONGESTION'S IMPACTS ON ECONOMIC ACTIVITY

Nature of Impacts[4]

Urban traffic congestion affects producers of economic goods and services in terms of business costs, productivity, and output. Congestion effectively contracts the market area for economic inputs, bidding up their costs, and therefore increasing businesses' production costs. Congestion also can hurt economic development in individual regions by thwarting business attraction and expansion and reducing the quality of life for residents.

Transportation system users have developed strategies to deal with increased congestion and reduced reliability. In the short term, travelers or shippers might change their mode or time of travel. Over the longer run, congestion might influence decisions about where people live and work, or where businesses locate. These types of adjustments can reduce – but not eliminate – the economic impacts of congestion.

Trucking Impacts. Congestion means longer travel times and less reliable pick-up and delivery times for truck operators. To compensate, motor carriers typically add vehicles and drivers and extend their hours of operation, eventually passing the extra costs along to shippers and consumers. Research on the trucking industry has shown that shippers and carriers value transit time in the range of $25 to $200 per hour, depending on the product being carried. (FHWA 2005a) Winston and Langer (2006) estimate the average value of an hour of delay for a truck to be about $30/hour, just for the shipment and not including the effects of inventory carry costs.

Impacts on Businesses. Congestion increases the costs of delivering goods and services, because of the increased travel times and operating costs incurred on the transportation system. Less obviously, there may be other costs, such as:

- The costs of remaining open for longer hours to process late deliveries;
- Penalties or lost business revenue associated with missed schedules;
- Costs of spoilage for time-sensitive, perishable deliveries;
- Costs of maintaining greater inventory to cover the undependability of deliveries;
- Costs of reverting to less efficient production scheduling processes; and
- The additional costs incurred because of access to reduced markets for labor, customer, and delivery areas.

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[4] This section is adapted from: Traffic Congestion and Reliability: Trends and Advanced Strategies for Congestion Mitigation (FHWA 2005b) and NCHRP Report 463, Economic Implications of Congestion.

The business value of time delay and market access act together to affect the profitability and revenue potential associated with doing business in a state or region. When one area is affected by congestion more than others, the relative competitiveness of these areas also shifts. The result is that businesses tend to stagnate or move out of areas with high operating costs and limited markets, while they locate and expand in areas with lower operating costs and broader market connections. The magnitude of these changes varies by industry, based on how strongly the industry's total operating cost is affected by transportation factors. The evidence seems to indicate that regional economies that are fostered by clusters or "agglomerations" of many interrelated firms are better positioned to counter the higher operating costs due to congestion than economies that are not.

Winston and Langer (2006) estimate the average value of an hour of delay for firms shipping goods to be about $34 per hour, as implied by the inventory costs of congestion. Adding this to the direct cost of trucking delay, this brings the total cost of an hour of delay to a truck shipment to be about $64 in 2000 dollars. This compares with an average value of passenger delay of $9.71 an hour.

Household Impacts. Households have both financial budgets and what is termed "time budgets" that are both impacted by congestion. Households plan their activities around their available time and financial resources. As time spent traveling increases, less time is available for other activities, including activities that directly or indirectly contribute to the economy (work, school, etc.). As vehicle operating and maintenance costs increase, the budget for other activities also decreases. The perceived "quality of life" of a neighborhood or region is diminished as well, when the safety, reliability and the convenience of the transportation system decreases. Studies have found that travelers tend to value travel time at about half of the average wage rate.

Regional Impacts. Regional economies are affected by these household and business-specific impacts. Diminished cost competitiveness and market growth opportunities are tantamount to a reduced ability to retain, grow, and attract businesses. Additionally, the redistribution of business and household activity to outlying areas and the direct delay for trips that are not diverted or otherwise changed may lead to decreases in air quality, increases in public infrastructure investment requirements, and impacts on health and quality of life factors.

Impacts of Reliability

Variations in travel time can be highly frustrating and are valued highly by both passenger and freight travelers. Research indicates that commuters value the variable component of their travel time between one and six times as much as average travel time. Furthermore, the increase in just-in-time (JIT) manufacturing processes has made a reliable travel time almost more important than an uncongested trip. Significant variations in travel time will decrease the benefits that come from lower inventory space and the use of efficient transportation networks as "the new warehouse." Businesses need to plan for the worst-case scenario, since delayed shipments will result in disproportionate costs if production activities need to be stopped and other resources are left sitting idle. Therefore, in both the passenger and freight realms, evidence suggests that travel time reliability is valued at a significant premium by users. The cost of unexpected delay can add another 20 percent to 250 percent to the previously cited values of travel time to shippers. (FHWA 2005a)

Impacts by Industry and Region

NCHRP Report 463, *Economic Implications of Congestion*, evaluates how congestion's impacts vary according to the type of business affected, location and scope of congestion reduction, and other factors. The report makes the following conclusions:

- Industries with broader worker requirements and higher levels of truck shipping absorb higher costs associated with congestion, and benefit the most from congestion reduction.
- Firms with lower-skilled labor requirements or nonspecialized commodity input requirements tend to be hurt relatively less by congestion.
- Congestion reduces the agglomeration benefits of urban areas by reducing access to specialized labor and delivery markets, with businesses adjusting through shorter trip lengths. Doubling the effective labor market size leads to an average 6.5 percent increase in business productivity.

A 2008 report for the U.S. Chamber of Commerce (USCOC 2008) examines the impacts of congestion by industry sector as well as spatial patterns. Some of the report's findings include:

- The location of U.S. economic growth is shifting. The South and West are continuing to grow, and the major metropolitan areas across the nation are being knit together into massive megaregions that are powering economic growth. Serving the passenger and freight transportation needs of these cities and their emerging megaregions will be a major factor in ensuring future economic health.
- In the **manufacturing and retail sectors,** staying competitive in the changing global economy means moving from large inventories and consolidated shipments to lean inventories and smaller more frequent shipments that support JIT manufacturing and replenishment-on-demand retailing. Metropolitan congestion is increasing delivery times, making it more difficult for retailers to ensure that they have the right products on the shelves at the right time.
- In the **manufacturing sector**, congestion, deteriorating travel-time reliability, and escalating costs are draining away the benefits of global supply chains and JIT manufacturing, increasing costs for consumers, and leaving supply chains less resilient to disruptions.

- In the **retail sector,** port congestion, tightening transcontinental rail and highway capacity, and mounting metropolitan congestion are making it more and more difficult for retailers to ensure they have the right products on the shelves at the right time and at the lowest prices.
- **Service industries** need access to large markets and big pools of skilled workers to keep costs down. But metropolitan congestion makes it difficult for service industry workers to get to work and for service industry customers to get to offices, medical facilities, schools, and other service centers. For many service businesses, congestion has forced them to add extra centers across metropolitan areas, to subsidize employee commuting costs, and to add drivers, equipment, and travel time to ensure delivery of their services to customers.
- The **agricultural and natural resources sectors** depend on efficient, reliable, and low-cost transportation to move U.S. agricultural commodities to trade gateways for export. These sectors have shifted demand to trucks due to lack of rail capacity and increasing costs for rail transport. Port access and throughput are not improving fast enough to keep costs down and meet seasonal demands for the movement and export of agricultural commodities.

Implications for Global Competitiveness

The NCHRP 20-24 Task 52 report, *Future Options for the National System of Interstate and Defense Highways*, notes that the growing integration of the global economy has placed the U.S. in an increasingly competitive framework with Asia and the European Union. In addition, trade and production interaction with Mexico and Canada constitute a significant proportion of the U.S. economy. The value of the nation's output is tied to high-value products such as electronics and automotive products. However, little net new capacity has been added in highways or freight rail. Trucks handle 92 percent of goods by value and 77 percent by weight, meaning that highway congestion has an especially significant impact on transportation productivity. The costs of U.S. products are further increased by congestion on the nation's railways and at international ports.

The NCHRP report suggests that firms' total logistics costs as a percent of GDP, which have been declining since the early 1980s, have recently plateaued and are starting to increase. (In 2006 these costs totaled about 10 percent of GDP, of which about two-thirds is for transportation and most of the remaining third for inventory.) While a combination of commodity, modal and network mismatches plus higher fuel prices are partly to blame, highway congestion and less reliable travel times were nearly as important, causing freight carriers to spend more on drivers and trucks, and shippers and receivers to hold larger inventories than in prior years. Congestion and unreliable travel times may have accounted for a third of the increase in inventory carrying costs in 2005. There is concern that the productivity of the highway freight system will continue to drop and that logistics costs will rise further in light of this growing freight capacity shortfall.

The U.S. Chamber of Commerce report examines relationships between transportation investment and the economy, including global competitiveness. The report concludes that while the U.S. business community has adapted well to the changing dynamics of the global economies and has achieved impressive increases in productivity, the margin of U.S. competitive advantage is shrinking in key sectors of the economy. Across all sectors, though, a reliable transportation system is critical to maintaining this margin. (USCOC 2008)

2.6 Studies of Congestion's Economic Impacts

This section highlights the findings of various studies that have examined the impact of congestion on economic activity and growth, either at a regional or national level.

The direct costs of congestion resulting from delay and wasted fuel are estimated by TTI to be $78 billion nationwide in 2005. (TTI 2007) Winston and Langer (2006), using TTI's congestion data but a lower value of time, place the total delay cost of congestion at $37.5 billion (in 2000 dollars). The authors attribute $10 billion of this cost to the freight sector, and note that while truck traffic represent only 5 percent of total vehicle miles, the freight sector experiences about 27 percent of congestion costs. The $37.5 billion estimate includes shippers' inventory costs (roughly $7.5 billion) in addition to direct travel-time and vehicle operating costs for truck and passenger travel.

A study of highway truck bottlenecks for FHWA located and estimated truck hours of delay for highway truck bottlenecks, based on data from the Highway Performance Monitoring System (HPMS). In 2004 the bottlenecks accrued 243 million hours of delay annually. At a delay cost of $32.15 per hour, the conservative value used by the FHWA's Highway Economic Requirements System model for estimating national highway costs and benefits, the direct user cost of the bottlenecks was about $7.8 billion per year. Over half of this delay occured at urban highway interchanges, with most of the remainder resulting from steep grades, signalized intersections, and lane drops. (CS-Battelle 2005)

In 2006, the Partnership for New York City sponsored a study that examined congestion's impact on the regional economy. Looking at a limited set of costs and industry sectors, the report estimated that severely overcrowded conditions on the region's streets and highways cause more than $13 billion in annual costs to businesses and consumers, $3.2 to $4.0 billion in lost economic output, and 37,000 to 52,000 lost jobs. The report concluded that "the level of traffic in the city and much of the Metro Region has crossed the dividing line that separates economically efficient traffic flow from destructive, excess congestion." Excess congestion (congestion occurring beyond economically efficient levels) was estimated to represent 48 percent of all regional congestion. Effects are distributed across all sectors but are most clearly felt in sectors such as manufacturing, wholesale trade, and construction that depends on freight movements.

A recent study of the Portland, Oregon region by Economic Development Research Group attempted to quantify the annual cost of highway and roadway congestion to the local economy. The study concluded, "As congestion continues to worsen, businesses in this region will be at a competitive disadvantage… Failure to address the negative impacts of congestion is likely to result in the loss of jobs as existing businesses expand elsewhere or relocate and the region attracts fewer new businesses." The study estimated that doubling planned investment levels in transportation improvements could result in saving 118,000 hours of vehicle travel per day (28 hours per household annually), resulting in a potential regional benefit valued at $844 million annually by 2025 ($782 per household) and 6,500 jobs. The potential benefit-cost ratio of this investment would be about 2:1. (EDRG 2005)

The Chicago Metropolis 2020 Freight Plan includes an analysis of the economic benefits of strategies to reduce VMT, including more compact and walkable land use configurations, a shift in investment dollars away from roadways and into transit, and congestion pricing on key roadways. The study estimates that annual time savings valued at $1.5 billion to truck traffic and $3.7 billion to auto commuting and on-the-clock travel will result, resulting in a $2.4 billion increase in personal income and a $4.3 billion increase in GRP. Additional investments to expand capacity on congested arterials experiencing high truck-traffic volumes would result in additional benefits of $141 to $367 million in personal income and $253 to $656 million in GRP, considering logistics costs savings as well direct time savings. (EDRG 2004)

A late-1990s analysis for the Los Angeles Metropolitan Transportation Authority (LAMTA) used the Regional Economic Models, Inc. (REMI) Model to evaluate the economic impact to Los Angeles County of three alternative transportation plan scenarios versus a no-build scenario. Each of the plan scenarios involved expenditures of about $9 billion (in discounted dollars) between 1998 and 2020 on a mix of highway and transit investments, with the majority in transit. The analysis found that the plan investments would have a net benefit to the economy (as measured in personal income, and subtracting out the plan's costs) of about $30 billion over this period, for a benefit-cost ratio of over 4:1. Including quality of life impacts, net benefits were expected to exceed $57 billion, for a benefit-cost ratio of over 7:1. (LAMTA 1999)

A number of studies using regional simulation models such as REMI have focused specifically on programs of transit investments. One study examined the benefits to the Salt Lake City region of an expedited series of transit investments, including light rail and commuter rail as well as improved bus service. The study estimated increases of $105 million in personal income and 1,400 jobs annually, with a benefit-cost ratio of 1.8 to 1. (Envision Utah 2005) Simulation models also have been applied in Chicago, New York City, and Philadelphia to measure the economic impacts of disinvestment in the region's transit system, which would result from greater highway congestion and travel times. For example, a 1991 study for the Delaware Valley Regional Planning Commission found that reducing Southeastern Pennsylvania Transportation Authority (SEPTA) service levels by 50 percent would result in 26,000 fewer jobs and $1.1 billion less personal income annually by 2020, while a full shutdown of services would result in would result in 170,000 fewer jobs and $9.6 billion less personal income – leading to a population loss of over 300,000 from the region. (DVRPC 1991)

These limited studies do not necessarily provide a comprehensive picture of congestion's economic impacts. However, they do suggest that the annual costs of congestion may run into the low billions in some large metropolitan areas. The direct costs alone (travel-time and vehicle operating costs) may be in the range of $30 to $80 billion nationwide each year.

2.7 The Effects of Rising Fuel Prices

As previously noted the average price of a gallon of gasoline crossed the $3 per gallon threshold for gasoline in August 2005 and exceeded $4 per gallon in June 2008. Diesel fuel was even more expensive, averaging over $4.50 per gallon in June 2008. These levels are unprecedented in the U.S. and, if sustained, could have significant implications for transportation demand and the structure of economic activity. This section, while avoiding the question of the overall economic impacts of rising fuel prices, discusses the potential implications of rising fuel prices for the evidence cited above on the economic impacts of congestion.

Some of the implications of rising fuel prices, and key questions or issues of uncertainty, include:

- To the extent that VMT increases are mitigated, congestion should increase at a lower rate or perhaps even decline (if capacity expansion keeps up with VMT growth). The economic impacts of congestion per se would therefore not be as great as projected, and the benefits of mitigation strategies similarly may be reduced. An outstanding question, though, is the spatial and temporal nature of VMT impacts. In particular, is peak-period travel showing proportionately lower decreases relative to all VMT, assuming that people have fewer options for eliminating nondiscretionary work travel? Or are peak-period decreases greater because options (i.e., transit service) are better during this period? Are there differences by metropolitan area that may be related to the quality of travel alternatives?

  Studies on the effects of mileage-based and congestion pricing may provide some evidence on the impacts of rising fuel prices on travel demand. Pilot studies of pay-as-you-drive insurance in Minnesota and Texas suggest that peak VMT will decrease more than offpeak VMT (the Minnesota study also suggests an even greater reduction in weekend travel). However, a study of mileage-based pricing in Oregon appears to have somewhat contradictory findings, showing a decrease in offpeak VMT but not peak VMT for those paying a flat mileage fee. Findings from the congestion pricing in London appear to suggest that the smallest VMT reduction comes in the a.m. peak, with larger (and generally consistent) reductions throughout the midday and evening peak-periods. This appears consistent with a peak pricing experiment in Washington State that found a VMT reduction smaller in the a.m. peak than in the p.m. peak (4 versus 11 percent). Based on these findings, one might conclude that gas prices will have the least effect on morning peak-period congestion, with a greater effect on evening congestion as well as offpeak congestion where it exists (when more trips are discretionary).

- Freight travel as well as passenger travel will be affected. However, the relative effect on passenger versus freight VMT is unknown. Elasticities of passenger travel with respect to cost have been well studied, but freight demand characteristics are less well understood. There already is evidence of mode shifting from truck to rail for long-distance shipment of certain commodities; the magnitude of this shift if high fuel prices are sustained is unknown.
- To the extent that travel under congested conditions increases fuel consumption and therefore vehicle operating costs, the economic costs of a given unit of congestion (i.e., hours of delay) will increase. This effect is relatively small but non-negligible compared to the value of travel time.[5] This effect will diminish, though, if new vehicle technologies (e.g., hybrids) continue to grow in popularity, as fuel consumption for these types of vehicles shows little relationship to congestion.
- Transit congestion will become an increasing concern as more travelers shift modes to avoid the cost of driving. Transit systems in some larger metro areas already experience significant peak-period capacity problems; this problem will only be exacerbated with rising fuel prices. Since transit service is generally subsidized, costs will rise if service is expanded to meet demand. Pressure may increase for expensive capital investment on rail systems operating at capacity.
- Analogous to transit congestion, congestion on the rail freight network will increase as shippers shift to more efficient modes. Critical bottlenecks already exist in the nation's rail system and with projected increases in freight traffic; much more substantial investment will be needed over the next two to three decades. Public agencies will increasingly be pressured to play a role in funding or otherwise helping facilitate investments in rail and intermodal facilities.
- To the extent that road traffic decreases and transit and freight rail traffic increases, there may be a shift (from roads to transit, rail, and intermodal) in the most effective ways to achieve economic benefits through transportation investment.

[5] For a truck the cost of an hour of idling would increase by about $2 if fuel prices rose from $1.50 to $4.00 a gallon, which is less than 10 percent of the value of time of a typical operator.

3.0 Summary of Congestion Management Strategies and Effectiveness

3.1 Introduction

This document reviews the state of knowledge on the full range of congestion management strategies and their effectiveness at relieving congestion. Strategies are organized into three broad categories addressed at reducing highway congestion:

- Category A – Adding capacity/physical improvements;
- Category B – Using existing capacity more efficiently/operational improvements; and
- Category C – Reducing demand for vehicle travel.

An additional Category D includes strategies for reducing congestion on transit vehicles. This category has been added in recognition of the growing demand for transit use in response to rising gasoline prices, which has led to transit agencies increasingly reporting concerns with overcrowded vehicles, especially during peak-periods.

Within these broad categories, 32 strategies are identified. Sections 3.6 through 3.9 provide summary evaluations of each strategy. The topics addressed in each summary include:

- A brief description of the strategy;
- Evidence on congestion relief benefits;
- Extent of current implementation;
- Potential applicability;
- Approximate costs of the strategy;
- Other implementation issues (institutional, political, etc.); and
- Potential solutions to these implementation issues.

The goal of these summaries is to identify not only the benefit of the strategy for congestion relief, but also the practical issues that affect the extent to which the strategy could be further implemented and therefore result in additional congestion reduction benefits nationwide, compared to current conditions. The summaries are based on a literature review of over 140 documents (some of which are summary documents themselves), combined with input from subject matter experts on each topic.

The information presented in this document is summarized in matrix format in Table 3.1. This matrix characterizes effectiveness, extent of application, and implementation issues on a "high/medium/low" or similar scale for each strategy. It should be noted that this matrix attempts to provide a highly simplified summary of some very complex issues. The actual effectiveness, applicability, or implementation issues for any particular strategy depend upon the specific details of the strategy and how and where it is implemented. Many of the strategy categories actually encompass a number of individual substrategies which may have very different impacts. For example, "transit enhancements" includes anything from more frequent bus service to signal prioritization to investment in fixed-guideway transit. In the matrix, significantly different subcategories are broken out for some of the categories of strategies discussed in Sections 3.6 through 3.9.

This research does not attempt to link individual congestion management strategies to economic growth outcomes, as there is very little evidence on which to do so. However, it may be inferred that individual strategies will result in economic growth benefits in rough proportion to their impact on congestion. The primary benefit is the avoidance of an economic cost to businesses, or the maintenance of an attractive economic climate. If congestion is allowed to get worse, then the evidence indicates that the region may experience economic harm. Some strategies, in particular those that affect freight movement, may have disproportionate impacts because of the greater economic value per vehicle affected. Others, especially new facilities, may have the additional benefit of opening up new land markets or customer markets for goods and services.

3.2 Discussion of Measures

This section provides an explanation of the key measures examined, and the meaning of the ratings applied in Table 3.1.

Effectiveness

For physical capacity expansion and operational improvement strategies (Categories A and B), the primary measures of benefit examined are traveler delay, travel times, and/or travel speeds, depending upon the specific measures examined in each study. Wherever possible, measures of benefit are reported in percentage terms in order to provide comparability across studies and strategies.

For demand management strategies (Category C), it is generally not possible to obtain benefit measures in terms of delay or travel times. Instead, demand management strategies are directed at reducing vehicle-miles of travel (VMT), which will have differing effects on congestion depending upon the spatial and temporal nature of the VMT reduction. For consistency, demand management strategy impacts are simply reported (where possible) as percentage reductions in VMT.

The effectiveness of transit strategies (Category D) can be measured in terms of maximum load factors (e.g., ratio of passenger-miles to seat-miles).

Table 3.1 describes congestion relief benefits at two separate scales:

- **Local –** The percentage benefit for traffic on the facility or intersection where the strategy is applied, for any specific time periods that it is applied; and
- **Areawide –** The percentage benefit for traffic at a network-wide level (e.g., city or metro area).

The scale used for rating effectiveness is:

- **High –** Strategy typically can provide at least a 10 percent impact (reduction in delay, increase in speed, reduction in VMT) at the scale noted;
- **Medium –** Strategy typically can provide in the range of a 2-10 percent impact;
- **Low –** Strategy typically can provide less than a 2 percent impact.

Table 3.1 Congestion Management Strategies: Summary of Effectiveness and Implementation Potential

				Effectiveness		Extent of Application		Implementation Issues		
		Strategy	Substrategy	Local	Areawide	Current	Potential Future	Cost	Noncost Barriers	Timeframe
A		Adding Capacity/Physical Improvements								
1.		New Roads and Roadway Widening		High	High	Moderate	Moderate	High	High	Mid- to Long-Term
2.		New Toll Roads		High	High	Moderate	Moderate	High/ Revenue-generating	High	Mid- to Long-Term
3.	a.	Managed Lanes (HOV, HOT, Express Toll)	Construction of new HOV, HOT, or Express Toll lane	High	High	Limited (four percent of metro fwy miles)	Moderate	High	Medium to High	Mid- to Long-Term
	b.		Conversion of existing general purpose lanes to HOV, HOT, or Express Toll	Low or Negative	Low or Negative	Limited	Limited	Low to Medium/ Revenue-Generating?	High	Short-Term
	c.		Conversion of existing HOV lanes to HOT or Express Toll	Medium	Medium	Limited (four applications in U.S.)	Limited (existing HOV lanes)	Low to Medium/ Revenue-Generating	Medium	Short-Term
4.		Truck-only Lanes		Varies	Varies	Limited (~three Interstate miles)	Limited (high-truck-traffic facilities)	High/ Revenue-generating?	High	Mid- to Long-Term
5.		Bottleneck Relief		High	High	Moderate	Moderate	Medium to High	Medium	Mid- to Long-Term
6.		Intersection Improvements		High	Medium to High?	Moderate	Moderate (new/ reconstruction)	Low to Medium	Low to Medium	Mid- to Long-Term

		Strategy	Substrategy	Effectiveness: Local	Effectiveness: Areawide	Extent of Application: Current	Extent of Application: Potential Future	Implementation Issues: Cost	Implementation Issues: Noncost Barriers	Implementation Issues: Timeframe
7		Intermodal Access Roads		Varies	Low	Limited (near intermodal terminals)	Limited (near intermodal terminals)	Medium to High	Medium	Mid- to Long-Term
8.		Access Management		High	Medium – High?	Moderate (~29 percent of urban arterials)	Moderate (arterials, especially new or reconstructed)	Low to Medium	Medium	Mid- to Long-Term
9.		Street Connectivity		?	?	Moderate (most older urban locations)	Moderate (areas of new development)	Low or Cost Savings	Low	Long-Term
B		Using Existing Capacity More Efficiently/Operational Improvements								
1.	a.	Traffic Signal Timing and Coordination	Traffic signal optimization and interconnection	High	Medium to High	Moderate – Extensive (25 to 60 percent signals optimally timed)	Extensive (all nonfreeways)	Low	Low	Short-Term
	b.		Centralized, actuated control systems	High	Medium to High?	Limited (major arterials, networks)	Moderate (major arterials, networks)	Medium	Medium	Mid-Term
2.		Changeable Lane Assignments		Medium	?	Limited (<250 miles in U.S.)	Limited	Low to Medium	High	Short-Term
3.		Congestion Pricing	Variable pricing on existing tolled facilities	Varies	Varies	Limited (~10 facilities in U.S.)	Moderate (any tolled facility)	Low/ Revenue-generating?	Low to Medium	Mid-Term
			Areawide pricing systems	High	High	None in U.S.	Unknown	High/ Revenue-generating	High	Mid- to Long-Term

		Strategy	Substrategy	Effectiveness		Extent of Application		Implementation Issues		
				Local	Areawide	Current	Potential Future	Cost	Noncost Barriers	Timeframe
4.		Ramp Metering	Real time metering based on mainline volumes/speeds	High	Medium to High	Moderate (1/3 fwys in 25 metro areas)	Extensive (all major metro area fwy systems)	Low	Medium to High	Short-Term
5.		Roadside Electronic Screening/Clearance Programs for Commercial Vehicles		Medium	Low	Moderate – Extensive (35+ states)	Extensive (all states)	Low to Medium	Low to Medium	Short-Term
6.		Loading Zone Management		Medium	Low	Extensive (most local zoning ordinances)	Extensive	Low	Medium	Mid-Term
7.	a.	Port Operations	Time-of-day pricing	High	?	Limited (two major ports)	Limited (major U.S. ports)	Low/ Revenue-generating	Medium	Short-Term
	b.		Alternative modes (rail, barge)	?	?	Limited	Limited (major U.S. ports)	High	Medium to High	Mid-Term
8.		Border Crossing Improvements		High	Not applicable	Limited (prescreening at 55/100 locations)	Limited (all border crossings)	Low to Medium	Low to Medium	Short-Term
9.		Incident Management		High	High	Moderate (~1/3 of metro freeways, ~five percent arterials)	Extensive	Low to Medium	Low	Short-Term
10.		Work Zone Management		High	Low	Moderate (some form in up to ~2/3 metro areas)	Moderate (work zones only)	Low	Low	Short-Term

	Strategy	Substrategy	Effectiveness: Local	Effectiveness: Areawide	Extent of Application: Current	Extent of Application: Potential Future	Implementation Issues: Cost	Implementation Issues: Noncost Barriers	Implementation Issues: Timeframe
11.	Traveler Information		Low to Medium	Low to Medium	Moderate/ Extensive (fwy network in most metro areas)	Extensive	Low to Medium	Low	Short-Term
12.	Road Weather Management		Medium	Low	Moderate	Moderate (inclement conditions only)	Low	Low	Short-Term
13.	Planned Special Events Traffic Management		High	Low	Moderate	Moderate (special event locations only)	Low	Medium	Short-Term
14.	Integrated Corridor Management/Active Traffic Management		High	Medium	Limited (pilot sites)	Moderate (major travel corridors)	High	Medium	Mid-Term
15.	Vehicle Infrastructure Integration		High	High	None	Extensive	High	High	Long-Term
C	Reducing Demand for Vehicle-Travel								
1.	Land Use		Low	Medium	Limited	Moderate (all new/redevelop areas)	Low or Cost Savings	High	Long-Term
2.	Road Pricing		High	High	None	Extensive	High/ Revenue-generating	High	Mid-Term
3.	Freight Demand Management		Varies	?	Limited (two major ports)	Limited (ports, CBDs?)	Low	Medium to High	Short-Term
4.	Nonmotorized Improvements		Low	Low	Moderate	Moderate	Low to Medium	Low to Medium	Long-Term

		Strategy	Substrategy	Effectiveness		Extent of Application		Implementation Issues		
				Local	Areawide	Current	Potential Future	Cost	Noncost Barriers	Timeframe
5.	a.	Transit Enhancements	Bus service and operations improvements	Low	Low to Medium	Limited	Extensive (bus systems)	Low to High	Low to Medium	Mid-Term
	b.		Rail transit construction	Low	Low to Medium	Moderate (new rail in ~30 metro areas)	Moderate (larger metro areas)	High	Medium to High	Long-Term
6.	a.	Commuter Choice/ Workplace TDM	Transit and ridesharing programs/ incentives	Low to Medium	Low	Limited to Moderate	Moderate (larger metro areas/ activity centers)	Low – Medium	Medium	Short-Term
	b.		Telecommuting and alternative work schedules	Low to Medium	Low	Moderate	Moderate (30-40 percent workforce)	Low	Medium	Short-Term
D		Reducing Congestion on Transit Vehicles								
1.		Transit Capacity Expansion		High	High	Moderate	Extensive	High	Low	Short- to Mid-Term
2.		Peak-period Pricing		Low to Medium	Low to Medium	Limited (a few agencies)	Extensive	Low	Low to Medium	Short-Term

Extent of Application

The "Current" application column is intended to provide an indication of the extent to which the strategy already is implemented, and therefore a baseline for considering the extent for further implementation. For example, estimates suggest that anywhere from 25 to 60 percent of traffic signals in the U.S. are optimally timed.

The "potential future" column is intended to indicate the extent to which the strategy could be implemented *in theory*, ignoring fiscal, political, institutional, and other constraints.

The rating for these categories also considers the extent to which the strategy is applicable only to specific areas (e.g., ports, central business districts) versus network/systemwide, which will affect the overall magnitude of congestion relief benefits that may be realized. *Temporal* as well as *spatial* extent is considered (for example, bad weather or special event strategies apply to only a small fraction of the time the roadway system is utilized). The following rating metrics are used:

- **Extensive –** Strategy can be applied to the majority of the urban roadway or transit system;
- **Moderate –** Strategy can be applied to perhaps 10 to 50 percent of the urban roadway or transit system; and
- **Limited –** Strategy can be applied to only a small portion of the roadway or transit system (less than 10 percent).

Cost

The cost rating is based on the following metrics:

- **High –** Typically major construction projects, other major infrastructure costs (e.g., areawide intelligent transportation systems), or costly services (e.g., transit operations) – ranging in the tens of millions per mile or per location covered, and the hundreds of millions for areawide applications;
- **Medium –** Modest infrastructure improvements (e.g., lane additions at intersections, more modest intelligent transportation systems or operational costs) – in the range of approximately $1 to $10 million per mile or per location covered, and the tens of millions for areawide applications;
- **Low –** Operations strategies (e.g., changing signal timing), minor construction, or strategies that primarily incur administrative/programmatic costs (e.g., land use policies) – typically less than $1 million per mile or per location covered, and the low millions for areawide applications.

Operating costs are noted where they are significant compared to capital costs. Social costs and benefits are not considered in this rating. However, some strategies (e.g., tolling) may be net revenue generators from a public sector perspective, and are noted as such.

Noncost Implementation Issues

These include political, institutional, and other barriers affecting feasibility. The following metrics are applied:

- **High –** Challenging barriers (e.g., strong political opposition or lack of public acceptance, major institutional coordination required) – typical for strategies with limited or no implementation;
- **Medium –** Some barriers, but have been overcome in practice; and
- **Low –** Few/relatively easy barriers to overcome.

Timeframe

Strategies differ widely in the timeframe over which their benefits are realized. Some – especially operational strategies – can be implemented in a relatively short timeframe. Major capital investments may take one to two decades to design, program, and implement. Some factors, such as land use, evolve and change over time. The following timeframe metrics are used:

- **Short-term** – less than five years;
- **Mid-term** – roughly five to 20 years; and
- **Long-term** – greater than 20 year timeframe.

These categories refer to the timeframe over which the *majority* of the strategy's benefits can be realized, if implementation begins now.

3.3 Interactive Effects

Some strategies have interactive effects, with greater impacts resulting from the combination than would be expected by simply summing the expected impacts of each individual strategy. There is not a good body of literature on the interactive effects of strategies, and therefore no clear expectations for how much more effective strategies will be in combination than individually. From a qualitative standpoint, however, some important interactions include:

- Demand management strategies targeted at personal travel are more effective when applied in combination. The benefits of a given investment in transit or nonmotorized facilities will be greater if supportive land use patterns are in place than if land use is not supportive. Similarly, a given workplace TDM incentive will have a greater impact if alternative travel modes are readily available and convenient – a function of land use patterns as well as alternative mode availability. Pricing strategies to reduce vehicle travel will similarly have greater effects when alternatives are more convenient and readily available.

- Some physical and operational strategies – in particular, managed lanes, street connectivity, and traveler information – also complement demand management.
- New roadways and roadway widening projects will retain their congestion benefits longer if they are implemented with access management principles, so as to prevent new development from eroding capacity. Connected local street networks can reduce the vehicle load on arterial roadways.
- Most of the operational strategies can benefit from a common information infrastructure, and therefore realize economies of scale in their implementation.

In contrast, some strategies may be somewhat redundant and therefore have lower combined benefits than expected by summing individual strategy benefits. For example, implementing both highway and transit capacity expansions in the same corridor will result in lower transit ridership than simply implementing the transit project; since the highway alternative has been improved, there is less incentive to take transit. Similarly, congestion pricing to manage peak-period demand should reduce or eliminate the need for capacity expansion in the affected corridor.

3.4 Implications of Rising Fuel Prices

The Section 2.0 discussion on congestion and the economy identifies the significant rise in fuel prices in the past three years and discusses some implications for that section's findings. This section discusses the implications of rising fuel prices for the congestion mitigation strategies discussed here. These findings suggest a continuation or acceleration of real-world trends that have been observed in recent years.

- Overall travel demand will increase at a slower rate than previously forecast or perhaps even decrease. However, this effect will be uneven, as some rapidly growing areas may to see aggregate VMT increases while slower-growing areas may see VMT holding steady or even decreasing. As a result, overall levels of congestion may be lower than expected.
- Major roadway capacity improvements may become less popular, while public support continues to increase for investment in transit and other alternative modes.
- Transportation funding problems will be exacerbated. Decreasing VMT will result in lower fuel tax revenues. At the same time, increasing fuel prices and demand for service will place growing pressures on transit agencies. The unit costs of road construction projects will rise due to rising costs for asphalt and other materials. Until a political solution is found to increase revenues, these factors will hamper efforts to reduce congestion (both highway and transit).

- Pricing strategies may become (at least temporarily) even less popular than they currently are, as opposition is likely to any strategy that further increases the perceived cost of driving. Whether this attitude will be sustained over the long term, or whether pricing will be increasingly perceived as an effective strategy to manage congestion and meet environmental goals, is uncertain.
- Individuals and businesses (perhaps combined with supportive public sector policies and programs) will increasingly engage in demand management actions such as telecommuting, transit incentives, and nonmotorized travel. Therefore, "baseline" implementation levels of these strategies will increase. The relative effectiveness of supporting public sector programs to encourage mode shifts or travel reductions also may increase.
- Similarly, support for efficient land development patterns that reduce vehicle travel will increase as people move closer to work or into walkable neighborhoods to reduce the need for driving.

3.5 Other Benefits and Disbenefits of Congestion Management Strategies

Many of the strategies described in this report have significant benefits in addition to congestion management and delay reduction, and some may have other costs (disbenefits) in addition to their monetary cost. These other impacts should be given the full range of consideration when making planning and investment decisions; effectiveness at relieving congestion is likely to be just one of many factors considered. Some general categories of other benefits and disbenefits, and the effects of various strategies, are described below.

Economic benefits of congestion management strategies are discussed extensively in Section 2.0. This section focuses on regional economic benefits that result from reductions in congestion and travel times, with corresponding improvements in accessibility and reductions in business costs. In addition, a project may have localized economic benefits or disbenefits. For example, the introduction of access control may negatively affect some businesses along the roadway alignment. Shifts in local traffic patterns may cause some businesses in higher-traffic locations to gain customers at the expense of other businesses where traffic is reduced.

Environmental benefits from these strategies may include reductions in fuel consumption and greenhouse gas (GHG) emissions, as well as improvements in air quality due to reduced emissions. To the extent that Category A strategies (adding capacity/physical improvements) result in smoother traffic flow (reduced idling and stops/starts), fuel consumption will be improved and emissions reduced. However, the benefits especially of major capacity expansion projects may be offset by "induced demand," or longer and more frequent trips that occur as a result of the project. Emissions and fuel consumption also may increase if the new facility accommodates high-speed traffic. Strategies in Category B (using existing capacity more efficiently) also will tend to reduce emissions and fuel consumption through improved traffic flow, and the offsetting effects of induced demand are likely to be much less significant since there will be less impact on vehicle destinations and routing. Category C strategies (demand management) will directly reduce emissions as a result of reduced vehicle travel, although strategies that increase transit service will result in some offsetting increases in emissions.

Some strategies may have negative environmental impacts. For the most part these will include major capacity expansion projects such as new or expanded roadways, or new transit systems. Negative impacts may occur on issues such as wetlands, water quality, natural habitat, and endangered species. Negative environmental impacts can often be significantly reduced or even eliminated through environmental stewardship and mitigation practices in design and construction.

Safety benefits may be realized from some strategies. Certain types of roadway capacity improvements should reduce crashes as new or redesigned facilities are constructed to modern design standards. Grade separations and access management are two types of projects that particularly improve safety by reducing conflict points. Truck-only lanes also improve safety by separating truck from automobile traffic. Many operational improvements improve safety by smoothing traffic flow, reducing stops and starts and thereby the incidence of rear-end collisions. Incident management has been demonstrated to improve safety by reducing "secondary" crashes resulting from congestion, lane-changing, etc. created by the initial crash. Work zone management protects highway work crews as well as keeping traffic moving more smoothly. Road weather management alerts drivers to hazardous conditions and helps identify avoidance strategies. Ramp metering can reduce crashes by spacing out vehicles merging into heavy traffic on a freeway.

Mobility benefits also may accrue to transit-dependent travelers, in addition to the broad mobility benefits to road users from congestion relief. Transit enhancements, transit subsidies, and nonmotorized improvements all benefit those who cannot or choose not to use a personal automobile for their travel. In some cases these benefits can result in critical economic benefits for individuals (e.g., access to jobs).

Community and quality of life benefits include aesthetics, noise reduction, recreational opportunities, and other benefits that are difficult to quantify. Intermodal access roads and other such facilities can remove truck traffic from residential neighborhoods. Nonmotorized projects are used for recreational purposes as well as for transportation. Commuter choice strategies such as teleworking and alternative work schedules can improve employee productivity and retention rates. Traveler information is valued by people for reducing uncertainty, even if their travel time is not affected.

Some strategies also may have negative community impacts such as increased traffic volumes, noise and vibration, physical barriers, changes in community character, and historic and archeological impacts. Again, the strategies with the greatest impacts are likely to be major capacity expansion/construction projects. As with environmental impacts, negative community impacts can often be significantly reduced or even eliminated through Context Sensitive Solutions practices and mitigation in design and construction.

Equity – Some strategies, particularly those that involve pricing, can have significant equity impacts depending upon how they are implemented. Pricing strategies that increase the cost of travel for all road users will impact low-income travelers proportionally more than high-income travelers. However, these negative impacts can be offset by using revenues from the pricing scheme to provide tax breaks or improve transit services that are used by lower-income travelers.

3.6 List of Strategies

The following strategies are discussed in Sections 3.6–3.9:

Section 3.6 – Category A: Adding Capacity/Physical Improvements

- A-1. New Roads and Roadway Widening
- A-2. New Toll Roads
- A-3. Managed Lanes (HOV, HOT, Express Toll)
- A-4. Truck-only Lanes
- A-5. Bottleneck Relief
- A-6. Intersection Improvements
- A-7. Intermodal Access Roads
- A-8. Access Management
- A-9. Street Connectivity

Section 3.7 – Category B: Using Existing Capacity More Efficiently/Operational Improvements

- B-1. Traffic Signal Timing and Coordination
- B-2. Changeable Lane Assignments
- B-3. Congestion Pricing
- B-4. Ramp Metering

- B-5. Roadside Electronic Screening/Clearance Programs for Commercial Vehicles
- B-6. Loading Zone Management
- B-7. Port Operations
- B-8. Border Crossing Improvements
- B-9. Incident Management
- B-10. Work Zone Management
- B-11. Traveler Information
- B-12. Road Weather Management
- B-13. Planned Special Events Traffic Management
- B-14. Integrated Corridor Management/Active Traffic Management
- B-15. Vehicle Infrastructure Integration

Section 3.8 – Category C: Reducing Demand for Vehicle Travel

- C-1. Land Use
- C-2. Road Pricing
- C-3. Freight Demand Management
- C-4. Nonmotorized Improvements
- C-5. Transit Enhancements
- C-6. Commuter Choice/Workplace TDM

Section 3.9 – Category D: Reducing Congestion on Transit Vehicles

- C-1. Transit Capacity Expansion
- C-2. Peak-period Pricing

3.7 Category A – Adding Capacity/Physical Improvements

Strategy: A-1. New Roads and Roadway Widening

Description: Construction of new freeways or arterials; adding lanes or shoulders to existing freeways or arterials.

Evidence on Congestion Relief Benefits

Adding capacity through road construction and widening has for many years been one of the traditional solutions to congestion problems. The primary question regarding their congestion relief benefits has been the extent to which expanded road capacity leads to "induced demand," both in the short term as people make longer or more frequent trips, and in the long term as people and businesses make locational decisions that may lead to more travel. Studies suggest that induced demand offsets some, but not all, of the congestion relief benefits of roadway construction and widening. As measured by the increase in VMT with respect to an increase in lane miles, estimates of short-term elasticity have ranged from near zero to about 0.4, while long-term elasticities have ranged from about 0.5 to 1.0, where 1.0 signifies that a 100 percent growth in lane-miles would result in a corresponding 100 percent growth in VMT. (Schiffer et al 2006)

Induced demand also may offset some of the congestion benefits of other strategies discussed in this document, although the effects are generally believed to be less than for major roadway investments which may open up completely new areas to development.

Extent of Current Implementation

General-purpose roadway construction and widening continues to occur, although primarily in areas of the southern and western U.S. that are experiencing the most rapid population growth. Most new limited-access highway construction is now in the form of tolled facilities, although construction and expansion of untolled arterial roads continues.

Potential Applicability

Road construction and widening is likely to continue in areas of rapid population growth. In some metropolitan areas, physical constraints on expansion will limit the new land area for development and most new urban growth will be infill and intensification, leaving fewer opportunities for new road construction.

Costs

Road construction and widening shows a considerable range of costs depending upon factors such as right-of-way costs, geometric requirements, intersections and interchanges, mitigation measures, etc. According to Florida DOT, new urban interstates may cost in the range of $10 to 12 million per mile, two-lane arterials about $5 million per mile, and four to six-lane arterials in the range of $6 to 9 million per mile. Additional lanes cost roughly $600 to 700,000 per mile (FDOT 2008). However, these figures do not include special items such as bridges, tunnels, and other major structural elements. A WSDOT study of 36 projects throughout the U.S. found that costs per lane mile (including all project costs) ranged from $1 million for simple widening projects in rural settings to $180 million for major urban projects involving bridges and tunnels, such as

Boston's Central Artery Project and Seattle's Alaskan Way Viaduct (WSDOT 2005). About one-third of these projects had costs in excess of $10 million per lane mile.

Other Implementation Issues

Barriers to roadway construction and widening have increased substantially in recent years. The most significant barriers include fiscal constraints and opposition due to environmental and community impacts. Geometric constraints can prevent widening of existing facilities in areas that are heavily built-up.

Potential Solutions

Solutions have included:

- Tolling of facilities as a finance mechanism;
- Incorporation of extensive mitigation features to minimize or offset environmental and community impacts;
- Bundling of roadway improvements with transit and nonmotorized improvements; and
- Corridor preservation strategies to protect excess right-of-way before development occurs, in order to facilitate future expansion.

Strategy: A-2. New Toll Roads

Description: Construction of new roads that are tolled.

Evidence on Congestion Relief Benefits

The impacts of this strategy are similar to the impacts of road construction and widening. However, because of the ability to moderate demand through pricing, tolled facilities may have the potential for greater long-term congestion reductions if tolls can be increased in response to growing demand. Toll roads also may have somewhat less of a congestion relief benefit to arterial roads if some traffic is diverted due to the toll rates.

Extent of Current Implementation

Most new limited-access highway construction, especially in the South and West, is now in the form of tolled facilities.

Costs

Capital costs for a sample of six recent toll road projects show a range of $3 to $11 million per lane mile, with an average cost of $8 million per lane mile (in 2008 dollars). Costs should be similar to new highway construction but with some additional costs for tolling facilities. An examination of operating costs for

14 toll authorities showed an average annual operating cost of approximately $1 million per center lane mile, ranging from a low of $100,000 to a high of just over $3 million. Across all of these authorities, operating expenses average 46 percent of revenues, ranging from a low of 24 percent to a high of 79 percent. Total operating expenses ranged from $7 million to nearly $500 million depending upon the extent of the system.

Potential Applicability

Largely as a result of public-sector fiscal constraints, it is likely that most new limited-access facilities will be tolled.

Other Implementation Issues

Community and environmental barriers are similar to the barriers to roadway construction and widening. Fiscal barriers can be partially or fully overcome using the projected revenues from the project. However, projects that are serving new corridors rather than existing corridors with heavy traffic are considered more risky and therefore may not have as much potential for private finance/investment. In addition, in some states there has been a public backlash against the construction and/or operation of roadway facilities by private companies.

Potential Solutions

Solutions have included:

- Careful traffic and revenue forecasting that provides the best possible information on the project's expected return on investment;
- Public-private partnerships, e.g., to guarantee a minimum revenue stream to private investors; and
- Incorporation of extensive mitigation features to minimize or offset environmental and community impacts.

Strategy: A-3. Managed Lanes (HOV, HOT, Express Toll)

Description: Constructing new lanes for high-occupancy vehicles (HOV), high-occupancy/toll (HOT), or Express Toll usage; converting general purpose lanes to these uses; or converting HOV to HOT or Express Toll lanes.

HOV lanes are reserved for the exclusive use of multioccupancy vehicles. HOT lanes are typically made available for the free use of HOVs (including transit vehicles), while other users can buy into the lanes at a price that is set to maintain free-flowing traffic. Express Toll lanes require all users to buy in, but again, at a toll set to maintain traffic flow. This strategy is related to the "congestion pricing" strategy described under operational improvements, since HOT and Express Toll lanes rely on congestion pricing for management of traffic volumes.

Managed lanes also can support the Transit Enhancements strategy by serving as infrastructure for express bus service or bus rapid transit (BRT).

Evidence on Congestion Relief Benefits

HOV lanes can increase the overall throughput of a roadway as well as reduce VMT, if they provide a significant time savings over general-purpose lanes, by increasing ridesharing and transit ridership. However, studies have found that HOV lanes are often underutilized and reduce overall congestion only under certain conditions, i.e., when general purpose lanes are allowed to become very congested. A study in Minnesota found that opening an HOV lane to general traffic would cause some mode shifting to SOV, but that overall person and vehicular throughput would still increase (CS/MnDOT 2002). A study in California – although controversial – found that such lanes have 20 percent lower capacity than other lanes and offer only small travel-time savings in most situations (Varaiya 2007). Construction of new HOV-only lanes would of course reduce congestion by adding capacity; but by inference, constructing equivalent new general-purpose lanes would have a larger congestion reduction benefit in most circumstances, unless the HOV lane is fully utilized.

Because of the underutilization of many HOV lanes, many transportation agencies are revisiting their existing or proposed HOV-lane operations to consider opening these lanes to general traffic, for a variable fee, with the intent of setting the cost of using the lanes high enough to keep them from becoming congested. These are so-called HOT (high-occupancy/toll) or managed lanes. Evaluations of HOV to HOT-lane conversions in Denver, Minneapolis, and San Diego have found a slight alleviation in congestion on the main lanes (e.g., 2 to 15 percent increase in travel speeds in Minneapolis) and substantially better utilization of the express lanes. The San Diego study observed no negative affect on carpool volumes; in fact, carpool volumes were found to increase, but this phenomenon was not repeated in Minneapolis.

HOV, HOT, and Express Toll lanes all depend upon congestion to be effective. Therefore, they only represent appropriate solutions in highly congested corridors in which it is not possible to solve substantially solve congestion problems through other means. While HOT and Express Toll lanes cannot eliminate congestion, they can reduce its economic impacts by ensuring that highly time-sensitive trips can be made in a timely manner.

Extent of Current Implementation

According to the ITS Deployment Database, 15 of 100 metro areas surveyed reported having HOV facilities, covering a total of 719 miles (four percent of freeway miles). Los Angeles, Denver, Salt Lake, Seattle, and Washington D.C. each had systems of at least 50 miles.

Approximately 28 miles of HOT lanes have been implemented in three cities to date – Denver, Minneapolis, and San Diego. The HOV lane on the Katy Freeway in Houston allows two-person carpools to buy into the lane during certain hours in which free travel is limited to three or more persons per vehicle.

Potential Applicability

New HOV or HOT lanes could potentially be constructed in any corridor in which congestion is severe and capacity can be expanded.

Conversion of existing HOV lanes to HOT lanes could conceivably be accomplished on much of the existing mileage of HOV lanes in the U.S. It would not be appropriate in situations where HOV lanes are fully utilized.

Conversion of some general-purpose lanes to HOV or HOT lanes could be accomplished, in theory, on much of the freeway network. However, this is unlikely to occur as the congestion benefits would not be significant (and, in fact, congestion might increase), except in exceptional circumstances where major time savings would induce a significant mode shift.

Costs

Costs for construction of new managed lanes would be expected to be on the same order of magnitude as for other road construction. Conversion of existing lanes would incur lesser costs for restriping, signage, etc., and in some cases lane control devices and barrier separation from general traffic. Operating costs for HOT and express toll lanes would be expected to be on the same order of magnitude as operating costs for toll roads. HOV and HOT lanes also would incur some enforcement costs to ensure that the lanes are restricted to high-occupancy vehicle use, although these costs would be offset by fines for violations.

Other Implementation Issues

Construction of new HOV or HOT lanes would run into political issues affecting any capacity expansion project, such as environmental impacts, operational and safety issues with interfacing the lanes with the existing roadway, concerns about induced demand, and privacy concerns related to toll collection and enforcement technology.

Construction of both HOV and HOT lanes is costly, although to the extent that HOT lanes can be self-financing through toll revenues, they may provide a more feasible alternative to untolled capacity expansion. In reality, few newly built HOT lanes can be self financing, because they are typically expensive (in dense urban areas), and much of the capacity is given away to HOV, leaving less room for toll payers.

HOV lanes may run into political opposition if they are perceived to be underutilized while general purpose lanes are still congested.

HOV to HOT conversions are much less expensive to implement, and should be able to recover operating costs, and at least contribute to the capital costs of conversion. The I-15 HOT lane in San Diego, for example, meets operating expenses and subsidizes increased transit service in the corridor. However, there is some political opposition to conversion of existing HOV to HOT lanes, on the grounds that: 1) it may reduce the relative benefit of carpooling and transit use, therefore reducing mode shifts and increasing overall VMT; 2) it establishes a precedent for tolling drivers (even if paying the toll is voluntary); and 3) it is perceived as inequitable in the sense that it allows wealthier people to "buy" their way out of congestion, while lower-income people may not have this option.

Potential Solutions

The potential solutions are similar to those for other pricing strategies, e.g.:

- Conduct well-thought out studies to evaluate the benefits of these options compared to other options, and effectively communicate the findings to the public and elected officials;
- Address equity concerns by redirecting revenues to support improved transit service, reducing revenue from other sources (e.g., fuel tax, general fund), and/or investing in other projects to reduce congestion, creating "win/win" solutions that benefit many different groups;
- Focus on applying pricing to new travel options rather than existing untolled facilities; and
- Address privacy concerns with appropriate technological and policy solutions.

Strategy: A-4. Truck-only Lanes

Description: Constructing new lanes (free or tolled), generally on Interstate, or other limited access highways, exclusively for the use of trucks.

Evidence on Congestion Relief Benefits

Among the general arguments in favor of truck-only facilities instead of or in addition to general capacity expansion are: 1) safety benefits of separating cars and trucks; 2) possibility of using longer/heavier vehicles than would be safe or practical on a shared use facility; 3) ability to finance such improvements with dedicated user fees/tolls; 4) the economic and environmental impacts of more efficient drayage movements between major ports and inland distribution centers; and 5) flexibility of rerouting in the event of a crash or other disruption on either roadway.

Studies of truck-only lanes/facilities have generally been site-specific, and include the following:

- A study by the Reason Foundation found that an east-west truckway facility running from the Ports of Miami to the airport and beyond to warehousing districts and rail yards northwest of the airport would remove 5,000 to 7,400 trucks per day from area highways in its first year of operation (2016), result in significant time savings for trucks and autos, and could feasibly be privately financed. (Poole 2007)

- A statewide truck lane study conducted by HNTB for the Georgia Department of Transportation found that adding truck lanes, if done in addition to (and not in place of) already planned general purpose capacity expansion, would yield modest benefits on I-75 and on highways in the Atlanta region, with 2035 V/C ratios decreasing from 0.82 to 0.78 on I-75 and from 0.82 to 0.80 on Atlanta-area highways. Adding truck lanes without also adding planned general purpose lanes would result in an increase in overall V/C ratios throughout the state. (HNTB/GA DOT 2007)
- A 2005 study by the Southern California Association of Governments (SCAG 2005) found that a $26 billion goods movement program, including at least $15 billion for truckways, would result in travel-time savings for truck drivers ranging from $100 each way for trips between the Ports of Los Angeles and Long Beach and downtown Los Angeles to over $300 for trips between the ports and the city of Victorville, site of many warehouses and distribution facilities.
- Other studies are underway, notably one study examining the feasibility of installing 750 miles of separated truck-only lanes on Interstate 70 through the states of Missouri, Illinois, Indiana, and Ohio.

Extent of Current Implementation

Currently the only truck-only lanes on the Interstate highway system are two segments of on I-5 north of Los Angeles, totaling less than three miles in length. Sections of the New Jersey Turnpike have separate cars-only and general traffic lanes, such that traffic on the general traffic lanes consists largely of trucks. There are a few examples of local roads for trucks only, such as the Haul Road in South Boston.

Potential Applicability

Based on research completed, there are at least two broad scenarios in which truck highways or dedicated truck lanes would be an appropriate alternative to consider for congestion relief:

- **Linking ports to inland distribution**. This is the case in both the Southern California and Miami studies, as well as the Portway project in northern New Jersey. In these locations, the existing highway network already is congested, carries a large number of trucks, and freight activity is projected to increase significantly. In both cases, studies have demonstrated that financing truck-only facilities through user fees would be feasible, and that these facilities could bring a strong return on investment to both their financial backers (in the Miami case) and to the freight shippers that use them.

- **Intercity/interstate freight corridors**. This is the case with the Georgia study and the Interstate 70 proposals. In these instances, long corridors are approaching capacity while freight volumes are projected to continue growing rapidly. Truck lanes in these instances are advocated for their safety benefits and the ability to permit longer and heavier vehicles.

Southern California is arguably the furthest along in the development of truckways, considering the number of studies completed and the fact that several truck-only facilities have appeared in the region's Long Range Transportation Plan since as far back as 1997.

Costs

The costs of truck-only lanes should be of similar magnitude to other managed lane systems.

Other Implementation Issues

Even modest deployment of truck-only lanes would necessitate major construction and a significant financial investment. More ambitious projects would approach the scale of constructing an entirely new highway. Projects of this size and scale are subject to a number of important issues:

- **Cost, design, and configuration.** As with constructing entirely new highways, the cost of constructing truck-only facilities can be enormous. Furthermore, when planning a long corridor, the area where the lanes may be most needed (in and around cities) also is where they will be most expensive and complex to construct. Under scarce and constrained transportation funding conditions, questions of finance and value are central to the planning and implementation of truck-only facilities. Related to the overall cost issue is that of design. Truck-only roadways that are separated from general-purpose lanes present design issues at interchanges, both in terms of physical layout (to avoid excessive weaving) and also access (tradeoff between more access points and less interruptions to traffic flow). Designing facilities that maintain safe interchange conditions, balance access concerns, and fit into often constrained spaces (possibly necessitating stacked roadways) significantly increase cost.

- **Benefits over general purpose lanes.** Generally, truck lanes will be widely opposed by the public unless it can be demonstrated that constructing a new lane for the use of trucks only would yield greater benefits to all users than would the same amount of new capacity applied to general use. This has been an issue in, among other locations, Georgia and the Seattle area. (Fischer et al 2003, HNTB/GA DOT 2007)

- **Long Combination Vehicle (LCV) operation.** Currently, both Federal law and many state laws regulate the maximum size and weight of trucks. While some roadways have been exempted from the standards, a Federal freeze on new exemptions has existed since 1991. LCV operation is generally regarded as a major potential benefit of truck-only lanes, and legislative changes would be necessary to make these facilities feasible.

- **Demand forecasting.** Studies completed to date have generally done a poor job of addressing the impact of tolling on diversion rates from truck-only lanes to other facilities. This is of particular concern during offpeak hours, when general purpose or nontolled roadways are uncongested. In addition, constructing excess capacity that may only be fully utilized during a few hours of the day may lead to political problems.

Potential Solutions

Fischer *et al* identified the need to conduct more detailed corridor studies that better predict usage as well as public and private benefits of truck lanes. These is a need to be site specific, but, as they point out, there is an overall need for better methods for examining issues such as: 1) specific safety benefits of truck-auto separation in a given facility; 2) the benefits and costs of allowing LCVs; 3) whether a truck-only lane results in greater overall benefits than using the same resources to construct an additional general purpose lane; and 4) the actual expected usage of a truck facility, over an entire 24-hour period. This final issue depends on total truck volume, but also on trip lengths, values of time, access to the facility, and time elasticity.

The following are general strategies for advancing the study and implementation of truck-only lanes:

- Incorporate truck-only lanes into regional freight studies and alternatives analyses for specific corridors;
- For roadways that connect ports and inland distribution facilities, work with port operators and shippers to develop offpeak travel incentives and innovative funding mechanisms to finance truck-only lanes while also equalizing demand for these lanes across the entire day; and
- Develop national or state-level guidelines for allowing LCVs on truck-only facilities.

Strategy: A-5. Bottleneck Relief

Description: Location-specific strategies such as grade-separating intersections, reconfiguring freeway/expressway entrance and exit ramps, and selectively widening roadways at bottleneck locations.

Evidence on Congestion Relief Benefits

Various studies have quantified the benefits of relieving highway bottlenecks, focusing on either individual sites or on the nationwide highway system. Benefits may be measured as time saved, money saved, fuel saved, reduced emissions, or fewer crashes and fatalities.

- A study by Cambridge Systematics for the American Highway Users Alliance (AHUA 2004) defined a "severe traffic chokepoint" as one in which drivers spend at least 700,000 hours per year in congestion, and identified 233 such bottlenecks in the U.S. highway system as of 2002. For the top bottlenecks, the report described planned (or proposed) improvements and estimated the benefits of implementing those improvements. Among the top 24 bottlenecks, improvements would result in at least a 70 percent reduction in peak travel time through all but one. These "mega bottlenecks" require major investments to fix their problems and these usually entail multiple strategies (e.g., combination of redesign, operational improvements, transit, and HOV).
- A Texas Transportation Institute study of four recently completed bottleneck projects in Texas, involving auxiliary lane construction, interchange reconfiguration, or lane restriping, found that in each case the projects benefits, measured as the value of time saved (safety benefits not included), outweighed cost in the first year alone. (TTI 2002)
- A FHWA study of several bottleneck projects in Minnesota sought to demonstrate that bottleneck relief projects, while not nearly as expensive as large-scale capacity expansion projects, can still yield significant benefits. Adding an auxiliary lane along three miles between two major interchanges on I-394 westbound increased peak throughput by 4,600 vehicles, decreased backups from six miles to none, and had an overall B/C ratio of 8:1. Eliminating a 6-4-6 lane drop bottleneck on less than one mile of I-94 in St Paul resulted in 3,200 vehicles of additional peak throughput, decreased backups from four-five miles to two-four miles, with a B/C ratio of 14:1 at a cost of $10.5 million. Improvements on Trunk Highway 100 (upgraded interchanges and an additional lane running between them) resulted in increased peak throughput of 14,400 vehicles, decreased backups from five-six miles to a quarter mile, and a B/C ratio of 13:1. This $7.1 million project was found to have similar congestion benefits as a $138 million rehabilitation of nearby I-494. (FHWA 2007c)
- Chicago's $1.5 billion CREATE program, a public-private partnership among the City of Chicago, State of Illinois, U.S. DOT, and multiple passenger and freight railroads, seeks to reduce passenger and freight congestion throughout the region by completing six rail-rail grade separations, 25 highway-rail grade separations, and numerous smaller improvements to the rail network. When complete, this series of projects will save drivers an estimated $72 million over the life of the project in reduced delay at the 25 new grade separations, as well as an additional $130 million in reduced delay at 163 remaining grade crossings due to more efficient train movements through the network; other benefits also will be significant. (CREATE web site)
- In another example of a low-cost bottleneck relief project, the Georgia DOT implemented fairly simple improvements to Atlanta's Downtown Connector

(I-75/I-85) such as restriping ramps to increase storage, and installing ramp meters. These improvements reduced severe delay hours by 38 percent. (FHWA 2007b)

Extent of Current Implementation

Bottleneck relief projects of all scales are continuously implemented at locations throughout the country, and on roadways under various jurisdictions. These vary in scale from small, local projects, such as rail-highway grade separations, to projects of regional or even national significance, such as Boston's $15 billion Central Artery/Tunnel project.

The 2004 AHUA study reports that seven of the top 18 bottlenecks from the previous edition of the study (1999) had undergone improvements and were no longer ranked in the 2004 report.

Potential Applicability

Numerous nationwide and regional studies have identified the most severe bottlenecks in terms of total annual delay. States such as Minnesota also have instituted project screening processes that identify the most worthy bottleneck projects.

Costs

The costs of individual bottleneck relief projects vary widely, but typically range on the order of a few million dollars to the low tens of millions, for construction projects such as interchange construction/reconstruction or widening of short segments.

Other Implementation Issues

In addition to the obvious barrier of cost whenever physical improvements are involved, highway bottlenecks are often the result of unique issues that have prevented earlier mitigation efforts. Many bottlenecks exist because of sections of roadway where expansion or other measures to relieve congestion may be especially expensive or controversial, such as narrow bridges, deep mountain passes, or sections of urban highway with adjacent homes, open space, or civic structures.

Some highway departments also may not fully recognize the relative frugality of some bottleneck projects over larger, more expensive capacity improvement projects. This might result in a focus on major projects when in fact much smaller-scale projects, while less glamorous, yield comparable travel-time benefits.

Potential Solutions

- Wider use of benefit-cost analysis and project prioritization criteria that include travel-time savings measures, to compare projects of all sizes on equal ground;
- Statewide bottleneck identification studies that go into greater detail than available national studies, which focus only on the nation's largest bottlenecks; and
- Set-asides for low-cost projects that can be quickly implemented and yield substantial congestion benefits.

Strategy: A-6. Intersection Improvements

Description: Turn lanes, roundabouts, continuous flow intersections, or other geometric reconfiguration to enhance traffic flow through intersections.

Evidence on Congestion Relief Benefits

In a 1998 study of "modern" roundabout installation in the United States, survey responses representing 38 early examples of modern roundabouts indicated that reduced delay and increased capacity were the top two benefits cited by state and local agencies that had installed roundabouts, with safety coming in a close third. Every respondent that reported at least one roundabout in operation indicated that it had reduced delay through the intersection (NCHRP Synthesis 264). A study of three roundabouts in Kansas also found delay reductions of 13 to 23 percent (IIHS 2001). The Insurance Institute for Highway Safety has released a number of reports and articles supportive of modern roundabouts on low- and moderate-volume roadways, for both safety and operational efficiency benefits. One such study examined 10 recently constructed or renovated signalized intersections in northern Virginia, with AADTs of between 14,000 to 41,000. The study concluded that all 10 intersections could have experienced lower average delay had they been constructed as roundabouts, with peak-period time savings ranging between 17 percent and 92 percent. (IIHS 2005)

FHWA's "Signalized Intersections: Informational Guide" (FHWA 2004) includes an entire chapter on "Alternative Intersection Treatments" that addresses nontraditional approaches to dealing with congestion and safety issues at signalized intersections. The following conclusions, generally derived from microsimulation studies, are some highlights from this chapter:

- Jughandles instead of traditional left-turn lanes may reduce overall travel time by 4 to 45 percent during peak conditions, depending on volumes and turning movement distribution. However, they increase the overall percent of stops, especially for left turners, and do not reduce travel time for left turners.
- A Michigan corridor microsimulation study found that when using median U-turns instead of two-way left turn lanes at intersections involving a

multilane divided roadway, overall travel time declined by 17 to 25 percent during peak hours, although the number of vehicle stops increased.

- Several simulations of continuous flow intersections (CFI) found that they can be highly effective at reducing delay, stops, and queue lengths, particularly when intersections are at or near capacity. One study found delay could be reduced by up to 85 percent at an "oversaturated" intersection.
- Split intersections, where the two approach legs of a major road are separated by at least 50 feet and one four-way intersection becomes two three-way intersections, may be effective when intersection volumes exceed 5,000 vehicles per hour. At 5,000 to 6,000 vehicles per hour, delay through a split intersection is 40 to 50 percent lower than through a traditional intersection, depending upon the percentage of left turns.

Extent of Current Implementation

Continuous flow intersections are still rare, but several pilot projects have been completed in recent years, and future research will determine the effectiveness of these installations. Similarly, there are still only around 1,000 modern roundabouts in the United States. However, recent studies have shown these to be a highly effective traffic control device, and as public acceptance of them grows (something that those studies indicate is likely to occur), they are likely to proliferate rapidly. Other techniques, such as jughandles, split intersections, and median U-turns, are widely in use in various parts of the United States.

Potential Applicability

Different solutions are applicable to different intersection types. Improvements such as jughandles, CFIs, and median U-turns are properly applied to major at-grade intersections where four-phase signal operation would be necessary without the use of some alternative arrangement. Modern roundabouts, on the other hand, are more typically suited to intersections involving two-lane roads, regardless of the number of legs in the intersection. One interesting application of roundabouts has been at lower volume highway interchanges with a "diamond" alignment. In these cases, there are two intersections with the nonhighway roadway, one on either side of the highway, at which both the exit and entrance ramp intersect the road. Each one, traditionally signalized or managed by a stop sign, is replaced by a roundabout. Examples of these can be found in Michigan and Colorado.

Physical intersection improvements can only be introduced when intersections are candidates for reconstruction or when designing new roadways. Implementation will therefore occur over a relatively long timeframe. Furthermore, geometric constraints will limit the ability to implement treatments that require a larger footprint at many locations.

Costs

A 1998 NCHRP study of roundabouts found that installation cost an average of $250,000, ranging from a low of $10,000 to up to $500,000. This is on the same order of magnitude as installing a traffic signal, which according to WSDOT, is approximately $250,000 to $500,000. Adding turn lanes or making other geometric improvements also might range in the tens to hundreds of thousands, depending upon the size of the project. In some cases, capacity may be improved at minimal cost, for example, by restriping lanes. Major improvements such as grade separation are likely to run into the low millions.

Other Implementation Issues

Roundabouts have traditionally been poorly perceived, especially *prior* to construction. Several studies by the Insurance Institute for Highway Safety have found stark differences between the perception of roundabouts before and after construction, with almost no detractors once installation is complete. However, overcoming the initial opposition has, in some cases, proven to be a major obstacle. Because of perceived (and actual) differences between driving habits and cultural norms between the United States and other countries where roundabouts are more popular, international case studies do not necessarily help in dispelling skepticism.

An important issue to consider with CFIs, jughandles, and other similar installations is their impact on pedestrians. While they do not pose an imminent danger to pedestrian safety, these types of intersections increase the total number of crossings, and in some cases require pedestrians to cross over two signal phases. These improvements also take up considerable space, leading to environmental and right-of-way acquisition issues.

Potential Solutions

- As the number of completed roundabouts in the United States continues to grow, high-profile studies that demonstrate the operational, safety, and aesthetic benefits of roundabouts will be needed to help drive them toward mainstream acceptance. Equally important, as a growing number of drivers encounter and become accustomed to driving in roundabouts, concerns about confusion and navigability will diminish. As an example, Carmel, Indiana, a suburb of Indianapolis, has implemented over 20 roundabouts, including several along two U.S. highways corridors and public reception has been positive.
- Better national and state-level guidelines for when and how to implement various “alternative intersection treatments” are needed.

Strategy: A-7. Intermodal Access Roads

Description: Constructing new or improved roads or other improvements (such as grade separations or upgraded traffic signal systems) to provide access to freight/intermodal terminals.

Evidence on Congestion Relief Benefits

Congestion benefits derived from improving intermodal access roads will be location-specific. However, few studies have quantified these benefits in terms of either time saved or financial benefits.

One particularly innovative study looked at creating a truck-only facility to link several intermodal facilities, warehouses, and highway interchanges in Chicago, and considered the benefits of applying Cooperative Vehicle Highway Automation Systems (CVHAS), such as automatic steering control, automatic platooning, or fully automated driving on these facilities. The study used a benefit-cost analysis and found that even a non-CVHAS such facility would yield over $3 billion in travel-time savings to the region, but that CVHAS would be feasible by 2015 and would result in a benefit-cost ratio of over 5:1.

Extent of Current Implementation

The majority of such improvements are initiated at the metropolitan planning organization (MPO) level, frequently making use of Federal transportation funds such as the Congestion Mitigation and Air Quality Improvement Program (CMAQ), Transportation Infrastructure Finance and Investment Act (TIFIA) loans, or other sources available to National Highway System (NHS) roads. The nationwide extent of intermodal access road provision, compared to intermodal access needs, is not known

Potential Applicability

Intermodal access improvements could be applied anywhere local streets connect major intermodal facilities with the regional/national highway network, where those streets are highly congested, or where congestion/air quality issues are affecting local residents and/or commuters.

Costs

Costs for intermodal access roads should be on the same order of magnitude as for other arterial streets, bridge structures, etc. NCHRP Report 497 reviewed 12 intermodal access projects, including some that involved road construction and widening, grade separation, and new interchanges. Costs were typically in the range of $1 to $10 million for local road improvements and $10 to $40 million for interchange and grade separation projects.

Other Implementation Issues

- **Funding.** Projects that address congestion into or out of a private intermodal facility are subject to heightened scrutiny when public funds are involved because of the perception that these projects primarily benefit private shippers. Similarly, intermodal terminal operators may be reluctant to contribute to improvements outside their property line if they believe that the benefits accrue primarily to the public.
- **Multiple stakeholders.** Projects generally have multiple beneficiaries and interest groups, and often require multiple sources of funding to complete. An important stumbling block is the lack of consolidated leadership. When leadership is lacking, multiple stakeholders will work at cross purposes; for example, intermodal operators will look to increase the volume and frequency of truck service while local governments seek to reduce truck traffic to minimize noise and environmental impacts on adjacent communities.
- **Increased truck volume.** Although congestion relief is generally beneficial to all parties, neighbors and other groups may oppose projects that relieve bottlenecks between highways and intermodal facilities if these improvements would cause a notable increase in overall activity at the facility.

Potential Solutions

- Develop strong coalitions among MPOs, municipalities, and the private sector to identify beneficiaries and divide financial responsibility. Case studies cited in NCHRP 497 suggest that the "lead sponsor" of a project may be any of these public or private sector stakeholders. Public-private partnerships are often required, so involving private sector stakeholders early in the planning process is a key to success;
- If a project involves multiple jurisdictions (especially multistate cases), establish a project task force;
- Conduct public outreach to determine solutions that will address congestion issues while remaining sensitive to local concerns about increased freight activity;
- When possible, incorporate individual improvements into a larger, coordinated, and often multimodal initiative; and
- Consider user fees, especially when there are multiple private beneficiaries.

Strategy: A-8. Access Management

Description: Reconstructing roadways and establishing local street and driveway design standards to limit access for midblock turning movements and meet minimum intersection spacing guidelines.

Evidence on Congestion Relief Benefits

Studies of specific facilities have found significantly improved travel speeds along access managed facilities. For example, a comparison by the Colorado DOT found average running speeds of 23 to 30 mph on six "regular" arterials, versus 46 to 48 mph on two "highly access managed" arterials. (CDOT 1985) One summary analysis reported that continuous two-way left turn lanes and/or nontraversable medians can result in a 30 percent decrease in delay, while long signal spacing with limited access can result in a 59 percent reduction in delay along an arterial corridor. (TRB 2003)

TTI estimates that the effect of existing access management along 29 percent of street miles in 85 metro areas was to reduce delay by 58 million person hours, approximately 3 percent of the principal arterial street delay. The percent reduction drops as the size of the urban area gets smaller. (TTI 2007)

Extent of Current Implementation

A survey of 85 metro areas found that all reported some level of access management in 2005, with the coverage representing an average of 882 or 29 percent of the principal arterial street miles in the cities. (TTI 2007)

Potential Applicability

Most state DOTs have some type of access management policy in place. Due in part to differing state legal frameworks, however, the amount of state control that can be exerted over access management varies. Some factors are fully under the DOT's control (e.g., design of new or reconstructed state highways) while others may be under local control (e.g., driveway access permitting and parcel connectivity requirements). Access management of local roads can be more challenging as local jurisdictions also must adopt appropriate policies and design standards. Overall this is a long-term strategy because roadway facilities as well as development patterns evolve over time. New arterial roads are generally being constructed according to access management principles, but it can require considerable capital investment to modify existing facilities.

Costs

Florida DOT estimates the difference in costs between an undivided and divided four-lane urban arterial to be about \$1.0 to \$1.5 million per mile (FDOT 2008). The costs of other access management strategies may vary considerably depending upon the specific strategy. Capital costs for median closures, intersection realignments, signalization, etc. may range from the tens of thousands to low millions. Driveway permit restrictions should involve only minor administrative costs. Additional local infrastructure may be required (e.g., to provide internal connectivity) but these costs should be offset by reduced capacity needs on the arterial street. Furthermore, some or all of the local infrastructure costs may be borne by the private sector.

Other Implementation Issues

One of the primary tensions in implementing access management is balancing the desire of property owners for direct access to their property, with the need to maintain safe and efficient traffic flow. Along commercial corridors, businesses often express concern about losing customers due to the circuitous routing required to access the business from the opposite side of the street.

Existing facilities can be costly or impossible to retrofit with access controls (e.g., medians) if right-of-way is insufficient. The local infrastructure required to support access management (e.g., local access roads, interconnected driveways) also may be difficult or impossible to implement due to geometric or fiscal constraints. Access management can be implemented much more easily on new facilities.

Potential Solutions

Some states have considerable legal authority to limit driveway access to state highways or otherwise control access. Others have had to take a more voluntary and cooperative approach, e.g., by working with local governments on development permitting processes and local street networks, and developing handbooks, took kits, and internal policy guidance to support implementation of access management. Cooperative relationships also can encourage local jurisdictions to adopt access management principles along arterial roadways not under state jurisdiction.

Local opposition can often be overcome by citing the preponderance of research showing that businesses are usually not hurt by access management, and in fact often benefit as a result of the improved traffic conditions in their vicinity.

Strategy: A-9. Street Connectivity

Description: Providing a connected local street network to remove traffic loads from arterials as an alternative to disconnected local street system containing cul-de-sacs and circuitous or discontinuous routing patterns.

Evidence on Congestion Relief Benefits

Local street connectivity was discouraged for most of the second half of the 20th Century in favor of a hierarchical street system that funnels traffic onto major arterials. Within the past decade, however, local street connectivity has been returning to favor as a way of reducing vehicle trip lengths, reducing traffic loads on arterials, and supporting pedestrian and bicycle travel. There is only limited evidence on the congestion relief benefits of this strategy, and depending on how it is implemented, street connectivity can potentially create more congestion on arterials by creating more intersections. It is often implemented in conjunction with two other strategies – access management and land use/ compact development.

One simulation study in Tallahassee, Florida found that improved connectivity can reduce arterial traffic levels; impacts are the greatest when the speed differential between the arterial and local streets is small and there is limited through traffic. For example, for a 40-mph arterial, connectivity improvements on 25-mph local streets could lead to a reduction in arterial traffic volumes of 11 to 16 percent. (Alba and Beimborn 2004)

Other studies have found lower VMT and higher rates of nonmotorized travel in traditional neighborhoods built on grid systems as compared to suburban cul-de-sac neighborhoods, although the impacts are often related in part to other factors such as the density, mix of uses, and accessibility to local and regional destinations (Ewing and Cervero 2001). For example, a study from the Puget Sound region found that each unit increase in intersection density (intersections per square kilometer) was associated with a 0.39 percent decrease in VMT per capita, controlling for other factors, including demographics, transit availability, population density, and mix of uses. This resulted in an estimated 19 percent less VMT and 14 percent less time traveling for residents of the urban Queen Anne neighborhood versus the suburban Redmond Town Center. (WSTC 2006)

Extent of Current Implementation

Connected street networks are increasingly being implemented in new subdivisions built in a "traditional" or "new urbanist" style, as well as along some commercial corridors and districts where local streets provide an alternative to arterial travel for short trips. For example, New Jersey DOT worked with local communities to develop a plan for the U.S. 202/State Route 31 area that included a new two-lane signalized roadway and internal circulation system, that addressed traffic issues at a considerably lower cost than providing a four-lane bypass of the area (NCHRP 2004).

Potential Applicability

This strategy could potentially be implemented for all new development that is occurring on a large enough parcel or subdivision to require creation of street infrastructure. In some suburban locations, greater connectivity is being introduced through extension of the existing street network.

Costs

Florida DOT estimates that two-lane arterials cost about $5 million per mile. Local streets should cost somewhat less than this. Local street connectivity may pay for itself, however, through reduced arterial capacity needs. The NJDOT 202/31 plan included a new two-lane signalized roadway at a cost of $50 million, along with a new internal circulation system valued at about $20 million (of which one-half would be funded by private developers), compared with the original proposed four-lane grade separated bypass which was valued at $150 million.

Other Implementation Issues

The following design challenges are associated with connected street networks:

- Connectivity may, in some cases, increase infrastructure costs if more street mileage needs to be provided;
- Connectivity can increase traffic volumes on residential streets, creating safety and noise concerns; and
- Connectivity creates more intersections, thereby potentially creating more conflict points, safety hazards, and congestion on through streets.

Institutional challenges also exist. Street connectivity is generally an issue that must be addressed cooperatively between state and local government, as the local jurisdiction is typically responsible for local roads, master planning, and subdivision or site plan approval, while the state DOT is responsible for connections to the state highway system.

Potential Solutions

A well designed network can yield most of the benefits of connectivity without the drawbacks. For example:

- Connectivity may be introduced in some locations for pedestrians but not for automobiles, to promote nonmotorized travel while reducing traffic volumes on local streets;
- The costs of increased local street length are often more than offset by the reduced need for capacity on arterials; and
- Intersections of smaller local streets with arterials may be right-turn only so as to not create the need for additional traffic controls or safety hazards from left-turn movements.

State DOTs can work with local jurisdictions to implement connectivity by adopting principles and guidelines for connectivity (including connections to the state system); participating in local master planning and development review processes; and developing sample design and development standards that local jurisdictions can adopt.

3.8 Category B – Using Existing Capacity More Efficiently/Operational Improvements

Strategy: B-1. Traffic Signal Timing and Coordination

Description: Retiming signals to reduce intersection delay; coordinating control of traffic signals along a corridor or network.

Coordinating traffic signals may involve upgrading signal equipment to enable coordination and adding or removing signals to promote traffic progression along a corridor. It also may involve the use of advanced software that continuously updates signal timing based on demand.

Evidence on Congestion Relief Benefits

Numerous case studies have been performed using both simulation and empirical observation to identify the benefits of traffic signal retiming at individual intersections, coordinating traffic signals along an arterial or over a subarea, and advanced methods such as adaptive signal control systems. Benefits are most frequently measured in terms of percent increases in travel speeds, reductions in travel times, reductions in delay, and/or reductions in vehicle stops, at the corridor (roadway) or occasionally subarea level.

The following national summaries of benefits were identified:

- A synthesis of various traffic signal retiming projects in several U.S. and Canadian cities found that traffic signal retiming can reduce delays by 13 to 94 percent, stops by 10 to 77 percent, and travel-time by 7 to 25 percent. (Sunkari 2004)
- Poor traffic signal timing accounts for an estimated 5 to 10 percent of all traffic delay, or 295 million vehicle hours of delay on major roadways alone. (Meyer 2007)
- A review of various case studies of preset-timing traffic signal coordination suggests that travel-time reductions in the range of 8 to 25 percent are possible. Studies of actuated traffic signal coordination have found observed or simulated reductions in travel times from 8 percent to as high as 41 percent, with delay reductions ranging from 14 to 44 percent. (IDAS Database)

Transportation professionals are in general agreement that regular retiming/ optimization of individual signals as well as coordination of signals along an arterial corridor or across a subarea is one of the most effective and cost-effective means of reducing traffic delay and travel times.

These benefits would be realized immediately (once changes are implemented). On the other hand, ongoing attention to retiming is required in order to maintain optimal flow as traffic patterns change – otherwise benefits will erode (especially for static timing patterns). FHWA guidelines recommend that jurisdictions assess corridors for retiming signals at least once every three to five years.

Extent of Current Implementation

Local jurisdictions throughout the U.S. vary in their attention to optimization and coordination of traffic signals. The ITS Deployment Database reports the following statistics from 2004 to 2006, based on 106 metropolitan areas surveyed:

- 104 reported having signalized intersections under closed loop or central control, representing a total of 53 percent of signalized intersections in these areas;
- 104 also reported having semi or fully actuated intersections, representing a total of 53 percent of signalized intersections in these areas;
- 95 reported having intersections that are progressively connected, representing 31 percent of intersections in these areas; and
- 30 reported having adaptive signal control systems, covering 3 percent of intersections in these areas.

Areas with the most significant benefits in their respective size categories include Los Angeles, New York, Denver, San Diego, Austin, Jacksonville, Omaha, and Colorado Springs (TTI 2007). The frequency of signal timing updates varies widely, ranging from annually to over eight years between retiming.

The 2007 National Traffic Signal Report Card shows scores of 60 percent for signal management practices, 72 percent for signal operation at individual intersections, 61 percent for coordinated signal operations, 70 percent for signal timing practices, and 70 percent for maintenance. These scores roughly correspond to the percentage of agencies with excellent practices. Seventy-two percent of agencies reported strong or outstanding procedures for updating signal timing parameters when performing a timing update. Sixty-two percent reported conducting a comprehensive review of areawide or corridor signal timings at least every three years. Nearly 60 percent of agencies perform a comparative analysis of cycle lengths, offsets, phase sequence, and other timing parameters as part of the evaluation and implementation of signal timings. (NTOC 2007)

Many jurisdictions do not routinely update or optimize their traffic signal timing or have not implemented adaptive coordination systems. Meyer (2007) estimates that over 75 percent of the 260,000 traffic signals in the U.S. could be improved by updating equipment or by simply adjusting and updating the timing plans. While this estimate addresses individual signals it does not address the extent to which additional coordination of signals could be achieved at a corridor or subarea level on a nationwide basis.

Potential Applicability

Routine retiming and optimization of traffic signals is something that could in theory be achieved in every political jurisdiction in the U.S. The extent to which traffic flow can be further improved by optimizing signal coordination across corridors or subareas may vary depending upon the local context. For example, the spacing of signals, roadway geometry, and spatial and temporal traffic patterns may have a significant influence on the extent to which additional optimization can be achieved.

Costs

For individual intersections, costs to retime signals are estimated at approximately $2,500 to $3,100 (U.S. DOT 2007c). A project to optimize over 12,000 signals throughout California cost $16.1 million, or just over $1,000 per signal (Skabardonis 2001). According to the 2007 U.S. DOT study, computerized synchronization systems cost $2.2 million for 600 signals in Salt Lake City, Utah ($3,700 per signal); $2.4 million for 65 intersections in Arlington County, Virginia ($37,000 per signal); and $8.3 million for 145 intersections in Syracuse, New York ($57,000 per signal). The Virginia system is expandable to 235 signals, and the cost of field equipment for the 65 in place was approximately $27,000 per signal.

Other Implementation Issues

The following barriers are noted to the more widespread implementation of traffic signal coordination and optimization:

- **Technical and financial resources.** This is especially a problem in smaller local jurisdictions which may not have the financial resources or technical know how to optimize individual signals, let alone implement coordination schemes. Costs are somewhat greater for implementing interconnecting signals and considerably greater for implementing adaptive control systems, due to the hardware and software requirements as well as staff knowledge. The fact that benefits largely accrue to individuals (through travel-time savings) rather than the government entities incurring the costs means that strategies may not be implemented even if their social benefits far outweigh their costs.
- **Institutional coordination.** Especially in smaller cities and towns, effective traffic signal coordination requires working with neighboring jurisdictions. Coordination also may be required with state or regional agencies that may have jurisdiction over certain roads.
- **Political issues.** Some jurisdictions may not want to optimize traffic flow but instead may want to encourage transit and nonmotorized travel through signal timing that is unfavorable to motorists. The need for equity in access (e.g., from side streets or particular neighborhoods) may limit the extent to which overall system efficiency can be optimized.

Potential Solutions

The following strategies have been identified to support traffic signal optimization and coordination on a more widespread basis:

- A set aside of regional transportation funding granted to local jurisdictions for the purposes of signal timing and coordination;
- Technical assistance from regional agency staff;

- A regional center for controlling and coordinating traffic operations on major streets (traffic operations center); and
- A regional management and operations committee that jointly sets coordination policies and advocates jurisdictional coordination.

Strategy: B-2. Changeable Lane Assignments

Description: Reversible freeway or arterial lanes, time restricted-use lanes, peak-period use of shoulder.

Evidence on Congestion Relief Benefits

Very limited evidence was found on this strategy. One study of reversible lanes on Memorial Drive in Atlanta found that a.m. peak travel times decreased by 25 percent in the major-flow direction and 5 percent in the minor-flow direction. P.M. peak travel times also decreased 24 percent in the major-flow direction and 4 percent in the minor-flow direction. In general, benefits are likely to be context-specific, but can be quite significant in situations in which flows are highly unbalanced. The increasing trend in suburb-to-suburb and central city-to-suburb commuting in U.S. cities suggests that this strategy is becoming less relevant over time.

Extent of Current Implementation

According to the ITS Deployment Database, as of 2006, 8 of 100 surveyed metro areas reported the use of reversible flow lanes on freeways, with a total of 98 miles (one percent) covered. Sixteen of 106 metro areas surveyed reported the use of arterial reversible lane centerline miles with automated lane management technologies (i.e., sensors and lane control signs used to implement reversible flow lanes). However, the total mileage affected is small (126), with the majority of that mileage in two metro areas – Janesville-Beloit and Fresno. There are a number of reversible lane applications in place for bridges, including several freeway bridges (e.g., San Francisco Bay Bridge, Walt Whitman Bridge in Philadelphia).

Potential Applicability

This strategy could potentially be deployed on arterials with no median and with strongly directional peak-period flows, but only where the roadway geometry and traffic flow conditions (significant differences in flow between directions of travel) are amenable to lane change operations. It could potentially be applied on freeway facilities where separated lanes can be constructed.

Costs

Little information is available on the costs of this strategy. The ITS Unit Costs Database places the cost of lane control gates and software in the range of $100,000 to $200,000 per location.

Other Implementation Issues

Operational challenges may be the largest barrier to this strategy, as the lanes need to be reversed in a safe manner. This is particularly true along arterials where there is no physical traffic separation and signage, markings, and signalization needs to be clearly applied to demonstrate the direction of travel in each lane. The operating agency must account for the required operations and maintenance of reversing the lanes twice each day. Furthermore, the strategy cannot be implemented along arterials with medians. Reversible lanes also are likely to encounter local opposition due to safety concerns and/or concerns over reduced capacity in the counterflow direction. The fact that the concept has been in existence for a long time but implementation is still quite limited suggests that the opportunity for future use of this strategy also is quite limited.

The potential for reversible lane construction along expressways is limited by right-of-way constraints as well as the need to provide regular access points for both directions of travel (and the limited opportunities for new construction along freeway corridors). As a result, reversible lanes are likely to remain a specialized strategy applied in only a limited number of locations.

Potential Solutions

New expressway reversible lanes could potentially be constructed as tolled facilities in order to overcome funding constraints.

Several strategies have been implemented to support lane changing operations:

- Moveable barriers operated by barrier moving vehicles;
- Use of service patrols to “sweep” lanes for vehicles trapped in lanes during barrier operations; and
- Use of CCTV cameras to monitor barrier operations.

Strategy: B-3. Congestion Pricing

Description: Proactively managing demand and available highway capacity by dynamically adjusting the toll paid by users or varying tolls by time of day.

Congestion pricing may be applied to existing tolled facilities, HOT lane conversions, a CBD or other cordoned area, a port, or to any other facility or network on which pricing technology can be introduced. Freight congestion pricing applied to specific port facilities is discussed separately under “Port Operations.” Congestion pricing can be contrasted with general road pricing policies, as discussed under Strategy C-2, which are intended to reduce overall vehicle travel rather than shifting it from peak- to offpeak-periods.

Evidence on Congestion Relief Benefits

A simulation of variable pricing’s impacts at a regionwide level was performed by the Washington State DOT, looking specifically at the Seattle region. This study predicted that regionwide value pricing would reduce delay by 55 percent compared to baseline forecast levels. This compares favorably with large-scale roadway expansion which was estimated to reduce delay on highways by 58 percent compared to baseline forecast levels. (WSDOT 2006)

Other studies have found shifting of travel from peak- to offpeak-hours on individual facilities or sets of facilities. The magnitude of the shift and the resulting congestion relief is highly dependent upon the specific pricing scheme implemented and existing traffic conditions.

Extent of Current Implementation

Variable pricing – in the form of either simple offpeak discounts or more involved pricing structures – has been implemented on a number of tolled facilities in the U.S., including the New Jersey Turnpike; Midpoint and Cape Coral toll bridges in Lee County, Florida; George Washington Bridge in New York City; State Roads 73, 133, 241, and 261 from San Diego to Los Angeles; Dulles Greenway in Loudoun County, Virginia; State Road 91 from Riverside to Los Angeles; and I-394 in Minneapolis-St. Paul. It also has been implemented in Stockholm and Paris.

Potential Applicability

Variable pricing has the potential to be applied on any facility which can be tolled. Its most immediate application is on roads and bridges that already are tolled. It also could be implemented on other limited-access facilities by adding toll collection. To date it has been studied on at least six other major facilities in the U.S. as well as for Manhattan and the Puget Sound region. The broader-scale application of this strategy beyond existing or proposed toll highway facilities is likely to require the universal deployment of electronic toll collection technologies.

Some observers believe that perhaps half of all future capacity increases on U.S. limited-access roadways will be toll-financed, with electronic variable pricing used to manage demand and ensure congestion-free travel. On the other hand, few believe that pricing will be applied to currently untolled facilities in the foreseeable future. (Kirby 2007)

Costs

Implementing variable pricing on existing tolled facilities involves only minor administrative and capital equipment costs (e.g., signage and other public information). Applying tolls to previously untolled facilities would require a somewhat greater capital investment, perhaps in the range of $200,000 to $400,000 for structures and equipment for a single toll plaza, in addition to ongoing operational costs.

Areawide congestion pricing schemes require substantial capital investment. For cordon pricing systems, the major cost components include roadside systems (gantries, cameras, etc.), back office systems (host, business systems), communications, and signage. Cordon pricing systems implemented in London and Stockholm required an initial investment of $400 to $500 million, or about $35 to $50 million per square mile covered. Annual operations and maintenance expenses of the London system are about $170 million or roughly 40 percent of annual revenues. For the New York City congestion pricing proposal, the "Mayor's Plan" was projected to incur $224 million in capital costs and $229 million in annual operating costs, representing about 35 percent of gross operating revenues. Other plans were proposed with lower ratios of costs to revenues.

In Oregon, a 2007 study of mileage-based road user fees found that statewide implementation would cost $33 million and also could be extended to congestion pricing schemes. While this system would require much less investment in field equipment than existing systems, it would require global positioning system (GPS) units in every vehicle. At current costs of $200 to $300 per unit this would run into the hundreds of millions for a major metropolitan area, although costs for these units are expected to come down in the future.

Other Implementation Issues

From a technical standpoint, variable pricing is relatively easy to implement on facilities that already are tolled. However, there is likely to be opposition especially regarding equity concerns – i.e., for low to moderate income travelers who do not have good options for shifting their time or mode of travel. Implementing pricing on currently untolled facilities will face numerous additional hurdles, including public opposition to paying for something that was previously free; the need for broader-scale deployment of toll collection technology; privacy concerns related to data collection and monitoring; and reluctance to cede control of transportation infrastructure to private entities (for privately operated facilities). Perhaps the biggest concern is likely to be diversion of traffic to other nontolled facilities.

Dynamic pricing (i.e., adjusting tolls in real time based on demand) is only likely to be effective on situations such as HOT facilities, where there also is an untolled option available. Otherwise, travelers will not have the information sufficiently far in advance to be able to adjust their travel patterns in response to the price. For other situations, static pricing – where rates are regularly evaluated and adjusted based on average demand patterns – is preferable.

Potential Solutions

The potential solutions bear similarities to those for other pricing strategies, e.g.:

- Conduct well thought out studies to evaluate the benefits of these options compared to other options, and effectively communicate the findings to the public and elected officials;

- Address equity concerns by redirecting revenues to support improved transit service, reducing revenue from other sources (e.g., fuel tax, general fund), and/or investing in other projects to reduce congestion, creating "win/win" solutions that benefit many different groups;
- Focus on applying pricing to new travel options rather than existing untolled facilities; and
- Address privacy concerns with appropriate technological and policy solutions.

In addition, proponents can focus on parallels with other demand-priced commodities (e.g., electricity) and market pricing as discounts for offpeak users rather than excess charges for peak users.

Strategy: B-4. Ramp Metering

Description: Metering of freeway on-ramp traffic during high demand.

Evidence on Congestion Relief Benefits

The Texas Transportation Institute reports that an average of 665 lane miles in 25 cities are metered (less than one-third of all the miles in the 25 cities), reducing delay by 29.4 million person hours, or approximately 2.4 percent of the freeway delay. Reductions in delay are estimated at 12 percent under "extreme" congestion, 8 to 11 percent under "severe" congestion, and 6 percent under "heavy" peak-period congestion. (TTI 2007)

Ramp metering has been studied in a number of individual cities, but most extensively in the Minneapolis-St. Paul region. Systemwide ramp metering has been found to increase freeway throughput by 30 percent and peak-period speeds by 60 percent, with travel-time decreases of 14 to 27 percent. Over a 14-year implementation period, peak-period freeway speeds remained 16 percent higher (from 37 to 43 mph) even while volumes increased 25 percent (ITS 1997). Results of an experiment in which the meters were shut down found that there was a 9 percent reduction in freeway volume, a 22 percent increase in freeway travel times, a 7 percent reduction in freeway speeds, and a 91 percent decline in travel-time variability (i.e., travel-time reliability was improved) (MnDOT 2001).

Studies of preset metering along freeway corridors have found freeway travel-time decreases of 7 percent (Portland, Detroit), 27 percent (Denver), 38 percent (Austin), and 48 percent (Seattle).

One drawback to most ramp metering evaluation studies is that they focus only on improvements in freeway conditions, and do not factor in the additional delay at ramp meters or congestion on local streets due to traffic diversion. The Minneapolis-St. Paul study found that if ramp delays are factored in, overall delay is still substantially reduced.

Extent of Current Implementation

Metropolitan areas vary in the extent to which they have implemented ramp metering. Minneapolis-St. Paul, Los Angeles, and Portland meter 100 percent of their urban freeway systems. The Atlanta region will be implementing 100 percent ramp meter coverage and Miami and Fort Lauderdale, Florida will be implementing ramp meters on I-95 later in 2008. Other areas have implemented metering only along specific freeway segments or at particularly high-volume locations. According to the ITS Deployment Database, 25 of 100 metro areas surveyed reported ramp metering on some portion of their freeway system in 2006. The average metered distance was 665 lane-miles which represents less than one-third of all the miles in the 25 cities. Ramp metering is primarily applied in larger metropolitan areas – of 46 areas studied with under one million population, only three reported any metering. (TTI 2007)

Potential Applicability

Metering could theoretically be implemented comprehensively in any major metropolitan area, but this has happened in only a few cases in part because of political opposition. It may not be technically feasible at some locations, e.g., in urban settings where queuing space is limited. Ramp metering programs currently are being considered in a number of major cities, including Charlotte, North Carolina, Des Moines, Iowa, and Cincinnati, Ohio.

Costs

The cost of ramp metering depends on whether the system is locally operated or under central control. According to the ITS Unit Costs Database, ramp metering equipment costs about $25,000 to $50,000 per unit and loop detectors cost $3,000 to $8,000 per unit. Hardware and software for "freeway control" is on the order of $200,000, with an additional $300,000 annually in operations and maintenance expenditures. (U.S. DOT 2007c)

Other Implementation Issues

The primary political barrier to ramp metering involves equity concerns, in particular, the perception that metering benefits suburban/long-distance commuters at the expense of urban and local traffic; and that excessively long queues at ramp meters delay local traffic. These concerns led to a shutdown of the Minneapolis-St. Paul ramp metering system in 2001, and its subsequent reinstatement (after traffic conditions worsened considerably) with modified metering patterns to reduce queuing.

Ramp metering also can involve a fairly complex set of infrastructure and control systems if it is to be implemented most effectively – i.e., with coordinated, traffic-actuated metering patterns. This requires a single, centralized control authority spanning multiple jurisdictions.

Potential Solutions

The following strategies have been identified to support ramp metering:

- Careful selection of potential ramp meter locations, including ramp storage capacity and relation to major bottlenecks;
- Meter rate algorithms that take into account the current volumes on the freeway mainline;
- Coordination between the ramp meter signal and the ramp terminal signal on the adjacent arterial; and
- Queue detection and management on the ramps.

Strategy: B-5. Roadside Electronic Screening/Clearance Programs for Commercial Vehicles

Description: Electronic screening and clearance systems to support selection of commercial vehicles for roadside inspections.

These systems enable safe and properly credentialed motor carriers to bypass weigh station facilities, thereby reducing congestion around weigh stations. In addition to time savings for motor carriers, they can eliminate queues upstream of weigh stations that create a congestion and safety hazard.

Evidence on Congestion Relief Benefits

In Oregon, the Green Light Commercial Vehicle Operations (CVO) project involved installation of Automatic Vehicle Identification (AVI) and Weigh-in-Motion (WIM) technology at 21 weigh stations and points of entry across the State. Between 2002 and 2012, the program was expected to prescreen 7.2 million trucks, saving 360,000 hours (time that would be spent at weigh stations) and $25 million to the trucking industry, as well as 0.15 to 0.17 gallons of fuel per prescreened truck. The program also eliminated the need to rebuild several weigh stations and increased overall compliance rates. (Bell 2001)

PrePass™ is a transponder-based prescreening system that enables enrolled trucks meeting predefined criteria to bypass weigh stations that have been retrofitted with the PrePass™ infrastructure. Currently 28 states participate in the program. In its first decade of operation, the PrePass™ system is estimated to have saved truck drivers over 20 million hours and over $1.4 billion (www.prepass.com).

Extent of Current Implementation

Some type of electronic prescreening for trucks is available in over 35 states and several Canadian provinces, primarily through the PrePass™, NorPass, and GreenLight programs. AASHTO has identified the states of California, Nevada, Indiana, Florida, and North Dakota as "lead states" in WIM and Virtual WIM deployment. These states use a mixture of bypass lane, mainline, and portable WIM arrangements. (AASHTO 2007)

Potential Applicability

Roadside screening and clearance is potentially applicable at any weigh stations or safety inspection facilities.

Costs

A 2001 evaluation of Oregon's Green Light program found that Oregon and three neighboring states had spent about $80 million to-date on PrePass infrastructure; however, states also were realizing revenues of about $1 million per month. (Bell 2001)

Other Implementation Issues

- Preclearance programs have different business models and may not meet the needs of all states;
- The motor carrier industry is not always receptive to the pay-per-pass concept;
- Safety benefits are not easy to quantify, reducing the ability to justify the program; and
- Many states do not have adequate staff resources to keep weigh stations open – prescreening is only a benefit at weigh stations when they are in use.

Potential Solutions

States must involve the motor carrier industry in advance of deploying electronic screening programs. Voluntary programs are generally more acceptable.

Strategy: B-6. Loading Zone Management

Description: Establishment and management of on-street and/or off-street loading areas to reduce impacts of loading vehicles on traffic flow.

Evidence on Congestion Relief Benefits

Freight pick-up and delivery may be a significant contributor to congestion on local streets in downtowns and other business districts. Strategies such as curbside and alley loading zones, offstreet loading dock requirements, and time and vehicle type restrictions can effectively reduce the traffic impacts of loading and unloading. However, no information is readily available to quantify the potential benefits of these strategies.

Extent of Current Implementation

Unknown; most cities manage freight deliveries to varying degrees.

Potential Applicability

Loading zone management is potentially applicable in all urban business districts.

Costs

Public-sector capital costs associated with this strategy would be minor and relate primarily to signage and pavement markings. Minor administrative and enforcement costs also would be incurred, with costs possibly recovered through fees or fines.

Other Implementation Issues

- Implementation is primarily the responsibility of the local jurisdiction, but requires coordination among different departments (traffic and parking, planning and zoning, law enforcement) as well as the support of local businesses;
- Competition for curb space (e.g., versus parking for businesses) can place political limits on the available curb space for loading zones;
- Geometric constraints may inhibit truck access in many built-up areas; and
- Loading dock requirements can only be applied to new construction.

Potential Solutions

A district/areawide freight study can bring stakeholders together to identify needs, solutions, and benefits.

Strategy: B-7. Port Operations

Description: Strategies to reduce truck delays at ports.

Evidence on Congestion Relief Benefits

Strategies to reduce congestion at ports include the following: 1) reducing peak-period activity and encouraging offpeak usage; 2) diverting truck traffic to alternative satellite locations through large-scale port-to-port movements (freight trains or barges, for example); and 3) using appointment systems to reduce gate queuing. The following are examples of benefits cited for these strategies:

- In Southern California, the PierPass Offpeak program at the Ports of Los Angeles and Long Beach has diverted more than five million truck trips from peak daytime traffic since the program's start in July 2005. The program included the creation of five offpeak shifts at the port, paid for by also instituting a peak-period "Traffic Mitigation Fee" of $50 per ton equivalent unit (TEU) on all containers. In an average week, offpeak removes 60,000 truck p.m. peak-period trips and substantially decreases trips during the

9 a.m. to 3 p.m. midday period (approximately 15 percent reduction in share of trucks).

- At the Ports of New York and New Jersey, the Red Hook Container Barge transports containers that arrive at the Red Hook Terminal in Brooklyn across the Hudson River to ports in New Jersey free of charge. The barge has diverted more than 70,000 containers of trucks that would otherwise use the severely congested Gowanus Expressway and Verrazano Narrows Bridge, which recently underwent a major reconstruction that substantially reduced capacity. Containers destined for New Jersey and points west can now be picked up in New Jersey, avoiding congested cross-Hudson bridges and tunnels.
- The Red Hook Container Barge was the basis for a subsequent initiative of the Port Authority of New York and New Jersey, called the Port Inland Distribution Network (PIDN). This project, currently in the planning stages, proposes establishing regular freight train and barge services to directly link the Ports of New York and New Jersey with nine satellite locations throughout the Northeast as far away as Pittsburgh, Pennsylvania, Boston, Massachusetts, and Buffalo, New York. Radii of 50 miles around each of the nine "dense trade clusters" represent 2.3 million TEUs of trade – 82 percent of the region's total. If fully operational, the network could reduce the share of freight moving out of the Ports of New York and New Jersey by truck from 82 percent to 38 percent. However, it is not yet clear whether this project will be economically viable due to the extra handling costs involved.

Extent of Current Implementation

The literature suggests that the majority of ports address congestion through traditional capacity expansion projects. Prominent examples of this approach can be found at the Ports of Seattle/Tacoma/Everett in Washington State with that region's FAST Corridor program, and in the Chicago region with the CREATE project. The PierPass program at the Ports of Los Angeles and Long Beach and the New York region's PIDN proposal are far more unique. A study of a California law that required either offpeak operations or the use of an appointment system found that the offpeak operations solution (implemented through PierPass) was the far more effective solution. (Giuliano and O'Brien et al 2005)

Potential Applicability

Port management strategies could potentially be applied at any major port facility where congestion occurs either at the gates or on surrounding roadways as a result of a disproportionate share of freight moving by truck, inefficient transloading operations, or significant peaking in port traffic during certain hours. Primarily these would be major ports on the east and west coasts.

Costs

For the PierPass program, the primary costs include operations of five new offpeak shifts at the port, as well as some administrative costs associated with the peak-period fee. From a public-sector operating cost perspective, the program is self sustaining as additional work shifts are paid for by the $50/TEU peak-period container fee. The Red Hook Container Barge is estimated to cost $59 million, including capital and operating costs but excluding private sector contributions. (NCHRP 497)

Other Implementation Issues

Cost and financing arrangements are the greatest barriers to any solution, whether in the form of a capacity enhancement or more innovative approach such as those at the Ports of Los Angeles/Long Beach and at the Red Hook Terminal in Brooklyn. Charging a fee for improved services, as is done at Los Angeles/Long Beach with the peak-period fee, may result in significant resistance from shippers. In the case of Los Angeles/Long Beach, shippers who are unable to shift to offpeak hours because of customer restrictions argue that they are being unfairly burdened. On the other hand, using public funds not only risks opposition from groups that feel such improvements amount to a subsidy for private companies, but also means uncertainty in securing ongoing funding. This latter issue has been a continuing challenge with the Red Hook Container Barge, which requires operating subsidies because it runs free of charge.

Potential Solutions

Current thinking is to develop inland ports or inland truck and rail terminals served by rail or truck shuttles. It is not clear that all shuttles would be cost-effective, but the strategy recognizes the pressure to redevelop waterfront properties for higher tax-revenue generating residential and retail uses.

Strategy: B-8. Border Crossing Improvements

Description: Use of technology and preclearance programs to reduce truck delays at border crossings.

Evidence on Congestion Relief Benefits

Congestion relief at border crossings for commercial vehicles is a significant challenge for inspection staff and industry. In many locations, the infrastructure is limited for the staging of trucks requiring more rigorous inspection. At the large commercial crossings, parking is constrained; at small rural crossings there may be little or no queuing area. Congestion mitigation activities are directly impacted by security requirements. Integration of new processes and tools, such as use of the Vehicle Cargo Inspections System (VACIS) – which is a gamma ray technology used to evaluate vehicle contents – increases the need for lay down areas for screening activities. As a result, preclearance activities have become a major component of border crossing activities. Preclearance programs are designed to expedite the processing of known shippers of low-risk shipments so that inspectors can focus on higher-risk shipments, and also to reduce the paperwork processing time at the border crossing.

Generally, approaches are similar to those used to expedite truck screening at weigh and inspection stations as part of the Commercial Vehicle Inspection Systems and Networks (CVISN) program. Primarily, this involves preregistration and preparation of shipment documentation and transponder-based screening. In addition to use of technology, some border locations have worked to improve the layout of their facilities by separating commercial and passenger traffic and improving site geometries. The following are several specific examples of ITS technology for trucks crossing the U.S.-Canadian border:

- The International Mobility and Trade Corridor (IMTC) partnership, a binational coalition of businesses and government entities in Washington State and British Columbia, worked with U.S. DOT and state/provincial transportation agencies to develop dedicated ITS truck lanes in both directions at the Blaine, Washington border crossing. The ITS improvements have been implemented, although dedicated lanes remained unfunded as of the study. Assuming modest participation (10 to 15 percent of trucks equipped with transponders), estimated time savings worth $30 million per year could be realized by 2013, primarily accruing to the trucking companies. A binational weigh station bypass system (eliminating “double weigh-ins” for safe and legal trucks) also was estimated to provide benefits, although with a lower benefit-cost ratio – this system was in the deployment process at the time of the study. (U.S. DOT ITS JPO 2003)
- A study led by Cornell University and Rensselaer Polytechnic Institute estimated that a transponder system implemented at the Peace Bridge crossing between Buffalo, New York and Fort Erie, Ontario, with 50 percent truck participation, would result in an average reduction in customs processing time of 66 percent for trucks and 35 percent for cars bound for Canada, with a 40 percent reduction in processing time for trucks bound for the United States. The savings would be the result of faster primary and secondary screening, as well as fewer vehicles sent to secondary screening. (Cornell/RPI 1999)

Extent of Current Implementation

As of 2007, the Customs and Border Protection Free and Secure Trade (FAST) program has been deployed at 55 of the 100 northern and southern border crossings, including those that handle the vast majority of all cross-border freight activity. This prescreening program allows expedited processing of registered drivers and carrying known low-risk shipments for companies that participate in the Customs-Trade Partnership Against Terrorism (C-TPAT) program.

Some border crossings continue to test and implement technology-based programs and to improve facility layout to accommodate inspection activities and incorporate new technologies/requirements such as the VACIS.

Many border crossing locations have separated truck traffic from the overall traffic flow. Examples include Blaine, Washington and Calais, Maine, where the original crossing went through downtown Calais, and the physical border crossing layout required poor truck access.

Potential Applicability

FAST could be expanded to include all border crossings where volume is sufficient to cause recurrent delay. In locations such as the Tacoma-Seattle-Vancouver corridor, where large quantities of goods arrive at ports in one country with final destinations across the U.S.-Canada border, it also is possible to integrate border crossing ITS applications with Automatic Vehicle Identification systems to track shipments from the port all the way across the border, thus streamlining the customs screening process and yielding significant time savings (U.S. DOT ITS JPO 2003). Improved queue management and layouts also could be considered to improve overall traffic flow.

Costs

The total investment for the Blaine, Washington ITS improvements was $4.35 million. As of 2003, this represented the largest single investment in CVO border crossing ITS technology in history. This investment is much less than the estimated annual benefits of the technology, with the benefit-cost ratio estimated to be at least 29:1. The weight station bypass system was anticipated to be somewhat more expensive to implement and to yield a benefit-cost ratio of at least 4:1.

Other Implementation Issues

- **Industry acceptance.** While the more progressive companies are willing to participate in the prescreening/known shipper programs, there still remains a significant opposition by many companies that are resistant to programs they believe will give the government inappropriate monitoring capabilities. This is improving as technology becomes more and more accepted, but it does limit a full deployment scenario.
- **Cost of entry.** The purchase and implementation of technology can be expensive; funding for equipping vehicles with transponders has historically been an obstacle as many trucking companies resisted investments in technologies that varied by state/region. Standardization over time has begun to minimize this obstacle.
- **Balancing efficiency and security.** Any program that prescreens trucks moving freight across the United States border must balance the desire for expediency with a continuing emphasis on security and antiterrorism efforts.

Many inspectors are resistant to a fully automated system as personal contact with drivers remains the preferred method for effective security screening.

- **Institutional barriers.** The Department of Homeland Security (DHS) is reluctant to share information with state CVO enforcement agencies (although cooperation at the road level is usually good).

Potential Solutions

Solutions must maximize both efficiency and security. The goal should be to equip trained inspectors with technology that can be used to streamline inspection activities without compromising security. Research and investment is needed in mainline screening technology that can identify threats and suspicious activity without the need to perform a full vehicle inspection. This requires implementation by DHS/Customs, however, rather than roadside CVO officers.

Other potential solutions include:

- Provide ongoing outreach/education to industry participants to increase acceptance and use of available technologies;
- Identify and improve physical/geometric barriers at border crossings to improve truck mobility and maneuverability; and
- Allocate user fees collected from the FAST program to continue performing regular site visits to C-TPAP participants both inside and outside the United States.

Strategy: B-9. Incident Management

Description: Identifying incidents more quickly, improving response times, and managing incident scenes more effectively.

Evidence on Congestion Relief Benefits

Incident management programs can have significant benefits for reducing unexpected or nonrecurring congestion. FHWA's IDAS model gives the following default values for reduction in incident duration: incident detection/verification – 9 percent; incident response/management – 39 percent; and combined incident detection and response – 51 percent. This is based on a review of existing studies on incident management program impacts. Since FHWA estimates that incidents cause 25 percent of all congestion, the benefits to overall congestion relief are therefore quite significant.

Extent of Current Implementation

Freeway incident management systems are relatively common although still covering only the minority of urban freeways. The ITS Deployment Database reports that as of 2006, 63 of 100 metro areas surveyed had some amount of their freeway system under surveillance, covering an average of 38 percent of lane miles. Seventy-three areas surveyed had service patrols on freeways, covering 46 percent of lane miles. Regions with some of the most extensive incident management programs for their size, based on ITS deployment information and benefits estimates, include Los Angeles, Minneapolis-St. Paul, San Diego, New York City, Austin, Nashville, and Louisville (TTI 2007). Other cities with extensive incident management programs include Atlanta, Seattle, Chicago, and Miami. Traveler-reported information is the most common way of detecting incidents (74 of 100 areas); with 48 areas using loop detectors and 19 using wireless enhanced 911 systems. Deployment of temporary traffic control devices and video imaging to assist data collection are other common incident management technologies.

Arterial incident management systems provide less extensive coverage. The ITS Deployment Database reports that as of 2006, 38 of 106 metro areas surveyed have arterial service patrols, covering 11 percent of the lane miles, with the most extensive deployments in Indianapolis, Nashville, Phoenix, Portland, and Santa Barbara. However, only a small percentage of arterial lane miles (less than 12 percent) are covered by incident detection and verification methods.

Management and coordination is an important aspect of incident management. Seventy-two of 106 metro areas surveyed operate one or more traffic management centers. Fifty-five of 100 reported some level of participation in a formal multiagency regional or statewide program (including strategic planning, program plan, and annual work plan) to coordinate management of traffic incidents. An example of an effective incident management coordination program is the Traffic Incident Management Enhancement (TIME) Task Force in the Atlanta region. The TIME task force has over 50 local agencies attending quarterly meetings and participating in activities on various aspects of incident management. TIME members have successfully lobbied the Georgia Legislature to enact quick clearance laws and a towing and recovery incentive program.

Potential Applicability

Incident management programs could potentially be expanded to all states and metropolitan areas. Since crashes occur everywhere and cause congestion when they do occur, this is a universally applicable congestion management strategy.

Costs

According to the ITS Unit Costs Database, establishing an Emergency Response Center or a Transportation Management Center (which may support multiple functions, including Incident Management) costs on the order of $5 to $10 million for a medium to large metropolitan area, with annual operating expenses on the order of $0.5 to $1.5 million. Hardware, software, and systems integration for incident detection may cost on the order of $400,000, with labor running $700,000 to $900,000 annually; incident response adds another $200,000 in capital costs plus $100,000 in labor for an incident management coordinator.

Other Implementation Issues

The primary barriers to broader deployment of incident management systems are institutional and fiscal. Incident management programs that do not involve heavy investment in infrastructure (e.g., roving tow trucks, cell phone detection) can be implemented at relatively low capital expense. However, effective programs require coordination between transportation agencies operating the highway system; state and local emergency response units; and other entities such as private-sector providers of traffic information.

Some incident detection strategies, such as closed-circuit TV, require more costly investments in infrastructure. However, traffic monitoring systems using cell phones or probe vehicles are reducing the need for these types of investments. Innovative methods also have been found of using existing traffic monitoring infrastructure (e.g., loop detectors) to identify the locations of incidents.

Potential Solutions

Establishing a regional coordination committee for emergency management, public safety, and incident management agencies can help to overcome institutional barriers to implementing incident management programs. Adoption of the National Unified Goal for Traffic Incident Management can promote better coordination, especially for on-scene management.

Strategy: B-10. Work Zone Management

Description: Reducing the amount of time work zones need to be used and moving traffic more effectively through work zones, particularly at peak times.

Work zone management strategies typically include offpeak scheduling, traveler information (including dynamic and traditional signage and Internet/television/radio media), variable speed limits, temporary contraflow lanes, and dynamic lane merging.

Evidence on Congestion Relief Benefits

Studies from work zones in several areas have shown reductions in vehicle delay and increases in throughput and/or travel speeds through work zone management policies. These studies focused mostly on technology-driven measures, including information and dynamic lane merging – information was not identified on the benefits of work zone management strategies that address time-of-day or day-of-week scheduling of road work.

Significant findings include:

- Evaluation of automated work zone information systems (AWIS) has found significant reductions in work zone delays primarily as a result of travelers taking alternative routes. A study in Los Angeles found that the traffic diversion from a freeway to arterials reduced overall VHT on the network by nearly 37 percent (SRF 1997). In North Carolina, a modeling study indicated that work zone delay messages contributed to 55 percent reduction in traveler delay (Bushman and Berthelot 2004). Evaluation of an AWIS on I-15 in California in conjunction with counterflow lane operations found that traffic demand through the work zone was greatly reduced, resulting in a maximum average peak delay that was 50 percent lower than expected (Lee and Kim 2006).

- An integrated approach in Albuquerque using work zone surveillance, dynamic message signs (DMS), and portable changeable message signs (CMS) reduce average incident clearance time by 44 percent when an incident occurred in a work zone (Dumke and Doyle 2001).
- Portable traffic management systems (PTMS) deployed at two Interstate work zones in Minneapolis-St. Paul increased work zone traffic throughput 4 to 7 percent during peak-periods as a result of more orderly flow.
- A dynamic lane merge system deployed in a work zone outside Detroit increased p.m. peak travel speeds by 15 percent, but did not change a.m. peak speeds.

Extent of Current Implementation

Work zone management appears to be used in about two-thirds of metro areas (although not necessarily on a comprehensive basis). The ITS Deployment Database reports that as of 2004, 67 of 100 metro areas surveyed reported that one or more operating agencies had deployed ITS technology at freeway work zones to take over the function of permanent systems that are degraded or made inoperative by construction activities, while 45 of 106 reported using such technologies on arterial work zones. Seventy metro areas reported that ITS was used within, or in advance of, work zones to improve mobility, enhance safety, and/or to manage incidents.

Potential Applicability

Work zone management practices could potentially be applied to any locations where significant congestion is expected to occur. Some of the more sophisticated practices require a traffic management center and communications infrastructure, e.g., to provide real-time information on traffic conditions.

Costs

A 1997 test of a PTMS in Minnesota found that one node with basic communication equipment cost around $80,000, with additional nodes costing $60,000. This is consistent with estimates in the ITS Unit Costs Database of $80,000 to $100,000 for a PTMS. The PTMS assumes the existence of a central control facility such as a Traffic Management Center ($5 to $10 million in capital costs, plus $0.5 to $1.5 million in annual operating costs) in order to support its functionality. Information also can be communicated through other communications methods (see Strategy B-11).

Other Implementation Issues

Technology-driven approaches to work zone management (e.g., those that involve communications through a traffic management center to provide real-time information) are only limited by the availability of ITS infrastructure and communication. The most sophisticated types of work zone management require transmittal and dissemination of real-time information on work zone conditions and transportation alternatives. More basic techniques may involve radio or telephone communication (e.g., 3-1-1 or 5-1-1 information lines).

Work zone management not only aids in reducing congestion, but also in improving safety for drivers and workers. However, work zone operations during nonpeak times often create an issue with compensation. Some labor unions insist that working on evenings or weekends should be met with increased wages. This issue can cause strain on project budgets.

Lack of communication between local, regional, state, and Federal agencies may prevent seamless implementation of work zone management. For example, repaving work performed by a municipal public works department may not inform a state-run ITS office where and when it will take place.

Potential Solutions

- FHWA has developed a work zone self-assessment tool[6] used by each State in 2003 to establish a baseline of their current state-of-practice and identify future work zone quality improvement efforts. Although the primary focus of this tool is assess safety conditions, the tool also addresses congestion and environmental concerns.
- Better communication between vertical levels of government can optimize the full potential of work zone management systems.
- A number of states have begun, including performance-based work zone management clauses in construction and paving contracts. These clauses require the contractor to provide prescribed work zone management techniques as part of their job.
- "Full Closure" work zones – where traffic is fully diverted from the target area – have been used in a limited number of areas but with large success. The advantage is that work can be completed much faster if traffic does not have to be maintained. Unfortunately, Full Closures can only be implemented where viable diversion routes exist.

[6] http://www.ops.fhwa.dot.gov/wz/decision_support/self-assess.htm.

Strategy: B-11. Traveler Information

Description: Providing travelers with real-time information on roadway conditions, where incidents have occurred and congestion has formed, how bad it is, and advice on alternative routes.

Evidence on Congestion Relief Benefits

The evidence on the congestion relief benefits of traveler information is limited and is largely strategy- and context-specific. In general, the ability of travel-time information to relieve congestion is largely dependent upon the availability of alternative routes (e.g., to avoid an incident or special event). To the extent that advance notice can be provided, some travelers also may be able to shift their time or mode of travel. The benefits also are dependent upon how the information is disseminated and how many people are able to access and make use of the information. The effect is nonlinear in the sense that if too many travelers choose to take an alternate route to avoid an incident, the alternate route may become overcongested relative to optimal traffic patterns.

One simulation study found that 100 percent market penetration of pretrip traveler information results in a 21 percent delay reduction when an incident occurs (IDAS Database). Most of the studies of traveler information systems, however, report benefits to travelers using versus not using the system, rather than systemwide congestion relief benefits. For example, operational tests of traveler information systems have shown travel-time decreases for informed travelers of 5 percent (Ali-Scout in Michigan) to 20 percent (TravTek in Orlando).

A review of existing literature by FHWA in developing the SCRITS (Screening Spreadsheet for ITS) model estimated that Highway Advisory Radio can save 0.7 percent of nonrecurring vehicle hours of delay, and Variable Message Signs 4.2 percent. (FHWA estimates that about half of all congestion is nonrecurring.)

Extent of Current Implementation

Various levels of traveler information are present in most major U.S. cities. Common forms of information delivery include traffic radio and Internet reports, "511" traveler information numbers, and dynamic message signs. The FHWA ITS Deployment Database reports that as of 2006, 63 of 100 surveyed metropolitan areas conducted real-time traffic data collection on freeways, covering 38 percent of lane miles, with loop detectors the most common technology. A total of 86 of the 100 metro areas had installed permanent dynamic message signs, with a total of 3,398 signs installed – 59 areas used these signs to display congestion information. Seventy-five also used portable signs. Many areas are posting expected travel times on dynamic message signs in addition to traffic alerts. The number of metro areas reporting the use of various information dissemination technologies was 52 (radio), 39 (511), 18 (Internet or wireless), and 13 (other telephone systems). As of February 2008, 30 states had established 511 information systems. The availability of traffic information for highways in major metropolitan areas is becoming widespread as demonstrated by the fact that one can view traffic speeds in over 60 U.S. cities on Google maps. Private providers of real-time information such as NavTeq/Traffic.com and Inrix have real-time traffic information available in about 75 metropolitan areas.

Potential Applicability

While traffic information is largely available for limited-access highways, it is not generally available for major arterial routes. This could represent a potential area of expansion.

Costs

Costs for providing traveler information can vary widely, depending upon the methods used for collecting as well as disseminating information. According to the ITS Unit Costs Database, establishing a Transportation Management Center (which may support multiple functions, including traveler information) costs on the order of $5 to $10 million for a medium to large metropolitan area, with annual operating expenses on the order of $0.5 to $1.5 million. Hardware, software, and systems integration for traffic surveillance also is on the order of $0.5 million. Hardware, software, and systems integration costs range from $0.1 million for "traffic information dissemination" at a Traffic Management Center to $0.5 million for "information service provider," with labor for an operator of about $100,000 annually.

Other components for providing traveler information may include roadside variable message signs ($40,000 to $120,000 each); information kiosks ($10,000 to $25,000 each, plus systems integration); highway advisory radio ($15,000 to $35,000); and an FM subcarrier lease ($100,000 to $200,000 annually). Additional functions, including interactive information, emergency route planning, and probe information collection typically cost a few hundred thousand dollars each.

Other Implementation Issues

The cost of deploying and maintaining roadside detection equipment is significant. Many agencies are finding the level maintenance of detectors required to provide quality data is difficult to fund and staff. For this reason large numbers of agencies are contracting out ITS equipment maintenance.

The proliferation of navigation devices, both in-vehicle and portable, that are connected to real-time traffic data sources is increasing the public's demand for real-time traveler information. Despite the high cost of implementation and maintenance of detection devices and the cost of purchasing private data, operating agencies will face increasing demand to provide real-time traveler information.

Potential Solutions

- The use of cell phones or probe vehicles for monitoring travel times has reduced the need for costly investment in monitoring infrastructure, and in some areas private sector companies are providing traffic information to operating agencies for a fee; and
- Performance-based contractor maintenance of detection equipment can support private maintenance of ITS equipment.

Strategy: B-12. Road Weather Management

Description: Prediction and detection of weather events (such as rain, snow, ice, and fog) in specific areas and on specific roadways, allowing for more effective road surface treatment and information for travelers.

ITS applications that assist road weather management support four major types of activities:

- Surveillance, monitoring, and prediction of weather and roadway conditions, which enable appropriate management actions to mitigate the impacts of adverse conditions;
- Information dissemination technologies to help road weather managers notify travelers of adverse conditions they may face on their trip;
- Traffic control measures enacted to improve traveler safety under poor weather conditions. A variety of technologies allow these control measures to be taken quickly in response to developing adverse weather; and
- Applications to support roadway treatments necessary in response to weather events. These applications may provide for automated treatment of the road surface at fixed locations, such as anti-icing systems mounted on bridges in cold climates. They also may enhance the efficiency and safety of mobile winter maintenance activities, for example, through automatic vehicle location on snow plows supporting a computer-aided dispatch system.

Evidence on Congestion Relief Benefits

FHWA estimates that bad weather causes about 15 percent of all traffic congestion. Road weather information systems may help alleviate some of this congestion, for example, by alerting transportation agencies to treatment needs or drivers to hazardous road conditions. Little evidence is available on the actual benefits of road weather information, however, and it is likely that only a small fraction of weather-related congestion could be alleviated by more effective advance treatment or information. One study of weather-related traffic signal timing (in response to at least three inches of snow) along a Minneapolis/St. Paul arterial corridor found that revised timing reduced vehicle delay nearly 8 percent and vehicle stops by over 5 percent.

Extent of Current Implementation

The ITS Deployment Database reports that as of 2004, 27 of 106 metro areas surveyed reported that one or more operating agencies had implemented traffic signal timing plans for inclement weather or slick pavement. Thirty-seven reported the use of in-pavement sensors to detect the condition of the roadway (temperature, water, ice, or anti-icing chemical concentration). Forty-eight reported the deployment of Road Weather Information Systems, with a total of 635 systems deployed.

The FHWA Management and Operations web site provides examples of road weather monitoring systems in Houston and Oklahoma. Warning systems for low visibility, flooding, and/or high winds have been deployed in at least 10 states. At least 13 states and municipalities have deployed decision support, control, and treatment systems. Salt Lake City, Utah has integrated weather information obtained from their environmental sensor system into traffic management center (TMC) operations.

Potential Applicability

Road weather management is potentially applicable in any area of the U.S.; however, the specific application will be dependent upon the nature of the weather conditions typically experienced in that area.

Vehicle infrastructure integration (VII) technologies represent a potentially significant means of expansion of road weather management. VII involves technologies in which vehicles communicate with each other and with central control locations through roadside communications infrastructure. With VII, vehicles can sense hazardous conditions and relay this information to the control center or other vehicles, so that system managers and drivers can take corrective action.

Costs

According to the ITS Unit Costs Database, a Road Weather Information System consisting of an environmental sensing station, central processing unit, workstation with software, and communications equipment may cost on the order of $50,000. Strategy deployment also requires the existence of a Traffic Management Center and other communications infrastructure (see Strategy B-11).

Other Implementation Issues

As in any detection system there are both implementation and operations/ maintenance costs associated with deployment of weather systems. In order to make use of the weather data there also are staffing costs to manually or automatically integrate the weather information with the TMC software. To date, no TMC has fully integrated weather data into their operations system and decision support tools.

VII is a long-term technology which needs to overcome significant institutional, technological, and fiscal barriers. Especially challenging is the broad-based coordination that will be needed to develop and implement the technology involving state transportation agencies, local jurisdictions, automobile manufacturers, telecommunications providers, and potentially other parties such as law enforcement personnel.

Potential Solutions

The following strategies have been identified to support real-time weather information:

- Obtain weather data from a variety of sources, including agency-owned sensors, the National Weather Service, and weather data providers;
- Continuously update weather information and fuse the various data sources;
- Automate the integration of weather data into the TMC operations software as much as possible;
- Develop TMC decision support tools that incorporate weather information; and
- Enable coordination between the TMC, the regional statewide Emergency Operations Centers (EOC), and other emergency management agencies.

A VII consortium has been established to determine the feasibility of widespread deployment and to establish an implementation strategy. The consortium consists of the vehicle manufacturers already involved in the Intelligent Vehicle Initiative, AASHTO, 10 state DOTs, and the U.S. DOT.

Strategy: B-13. Planned Special Events Traffic Management

Description: Pre-event planning and coordination, development of traffic control plans, coordinated operations during the event, and postevent debriefing.

Evidence on Congestion Relief Benefits

The benefits of this strategy are not widely documented and are likely to be highly context-specific. The available evidence suggests that advance planning for major events can have significant benefits in avoiding or reducing serious congestion problems at specific times and places coinciding with major events. For example, studies of the 1996 Atlanta and 1984 Los Angeles Olympics found that pre-event information, traffic management, and alternative mode provision actually led to a *decrease* in traffic congestion especially as a result of shifted or foregone trips. A study of a portable event management system in Atlanta found that it could reduce time for traffic to exit the event by as much as 50 percent. To contextualize these benefits, however, it should be noted that special events are estimated by FHWA to cause less than five percent of all traffic congestion.

Extent of Current Implementation

The ITS Deployment Database reports that as of 2006, 82 of 106 metro areas surveyed reported having some sort of special event management systems, such as traffic signal operation plans, temporary lane restrictions, traveler guidance, or other measures, implemented by one or more operating agencies within their region.

Potential Applicability

Event planning and management is applicable to any event whose time and location is known beforehand. Examples can include major events such as Olympic Games, Super Bowls, and political conventions; recurring events such as professional and college football games; or smaller events such as concerts or festivals. Even weather events or disasters like a hurricane evacuation can be considered to be a planned event.

Costs

Cost data on this strategy are not readily available. The costs of event planning and management may vary widely depending upon the nature and magnitude of the event, level of coordination required, etc. Some of the costs for this strategy include provision of information through various media, as described under Strategy B-11.

Other Implementation Issues

A number of operating, emergency management, and public safety agencies must be involved in the planning and implementation of event management. The first major institutional issue in event planning is getting the necessary agencies to cooperate. Next, all these agencies must agree on roles and responsibilities for both the planning and the operations. Finally, each agency must agree to provide the needed event staffing and equipment. Typically the event planning and operations will come from agency operations/maintenance budgets and most agencies do not have surplus funds available for these types of activities.

Potential Solutions

The following strategies have been identified to support event planning and management:

- Develop an event planning committee that meets on a regular basis prior to the event;
- Obtain agreements on roles and responsibilities, staffing, and equipment from each participating agency prior to the event;

- Use available fixed or portable ITS equipment for traffic management whenever possible; and
- Conduct post event debriefings with the planning committee in order to refine future plans.

Strategy: B-14. Integrated Corridor Management/Active Traffic Management

Description: Integrated Corridor Management (ICM) is the coordinated management of traffic controls, lane assignments, information, etc., across a corridor. The U.S. DOT currently is funding eight ICM demonstration projects in cities across the U.S. The term Active Traffic Management has been used in Europe to describe a similar approach. Active Traffic Management has been defined as a series of strategies to dynamically manage roadways and corridors in a manner that is responsive to both recurring and nonrecurring sources of congestion, such as bottlenecks, accidents/incidents, road work, special events, and poor weather conditions. This operations approach to congestion mitigation focuses primarily on using dense instrumentation along with remote traffic management centers, preferably coupled with a high degree of automation.

A 2007 FHWA International Scan of Active Traffic Management strategies widely in use in Europe but not in the U.S. included the following:

- **Speed harmonization –** Reducing speeds in advance of a major bottleneck or slowdown to minimize the impact of the congestion event and increase overall throughput;
- **Temporary shoulder use –** Using the shoulder of a roadway, in conjunction with Speed Harmonization, to increase capacity during peak-periods;
- **Queue warning display systems;**
- **Dynamic merge control –** Selectively metering or closing ramps and upstream lanes based on demand to maximize throughput and give priority to the higher-volume upstream source;
- **Dynamic rerouting and traveler information –** Using dynamic message signs to display rerouting instructions to motorists in response to nonrecurring congestion events; and
- **Dynamic lane markings –** To complement other strategies.

Other strategies more commonly used in the U.S. include managed lanes as well as rapid incident response using automated incident recognition and dispatch systems.

Evidence on Congestion Relief Benefits

Integrated Corridor Management and Active Traffic Management are relatively new concepts. One of the next tasks in the U.S. DOT's ICM program will be to calculate estimated benefits. However, it can be assumed that congestion relief benefits will be greater than the benefits of individual components, some of which have been shown to be quite significant (e.g., coordinated traffic controls). According to the 2007 FHWA International Scan, various European countries have experienced a 3 to 7 percent increase in peak-period throughput and a 3 to 22 percent capacity increase from Active Traffic Management, as well as significant reductions in incidents (up to 50 percent).

Extent of Current Implementation

Some agencies with advanced ITS programs have implemented combinations of strategies in particular corridors. For example, the Washington State DOT has been aggressively pursuing operations-oriented improvements for many years, including incident management, ramp metering, and travel conditions and commute-time information. Many urban areas also operate traffic management centers that collect large quantities of real-time traffic data through the use of loop detectors and CCTV, and can respond to congestion events and incidents with the use of dynamic message signs, incident response teams, and signal retiming. Variable speed limits and dynamic rerouting are in more limited use in the United States, with the most prominent example of these practices being the New Jersey Turnpike, which has used both technologies for decades. The U.S. DOT's ITS program includes ICM Systems as one of nine major initiatives, and the DOT is supporting ICM programs in eight locations throughout the U.S.

Potential Applicability

The ICM initiative will further demonstrate the viability of this approach for widespread implementation. A comprehensive Active Traffic Management system is most logically deployed at the corridor level, and would be most easily applied to corridors that already have managed lanes or are otherwise instrumented for traffic management, thus reducing the upfront infrastructure cost.

Costs

Installation cost would depend on the level of instrumentation already in place along the desired corridor, the existence and technological capabilities of a regional traffic management center, and the specific types of management approaches to be implemented. However, even in areas already instrumented for traffic monitoring, strategies such as speed harmonization, lane management, or dynamic merge controls would require considerable capital investment. Costs for many of the relevant systems (Traffic Management Center, traffic monitoring, etc.), including operations as well as capital, are described previously. The ITS Unit Costs Database places the cost of lane control gates and software in the range of $100,000 to $200,000 per location. Some unit costs are relative minor (e.g., less than $5,000 for a variable speed limit sign).

Other Implementation Issues

In the United States, there remains a lack of research exploring the benefits of Active Traffic Management as a comprehensive approach to congestion management. Additionally, many of the technological aspects of the approach, such as dynamic merge controls, are virtually nonexistent in this country, meaning that instituting such technology would likely require a robust public education initiative and a period of acclimation, prior to which the technology would temporarily lead to increased delays as drivers became accustomed to it. Related to that issue is the public opposition that would likely occur in response to proposals such as speed harmonization that may be perceived to lead to an increase in delay, although the opposite is in fact true. This is similar to the experience of many jurisdictions in constructing modern roundabouts, which are frequently met initially with strong opposition. Another issue related to speed harmonization is enforcement. If drivers do not respond to a systemwide queue to reduce speed in spite of what appears at the time as freeflow roadway conditions, the system will be ineffective.

Experience in Oakland, California as part of the ICM initiative as found that technical challenges are relatively easy to deal with and operational challenges can be addressed as well. Institutional challenges, involving many disparate stakeholders, are the most difficult. (LaPlante 2007)

Potential Solutions

One obvious solution to the cost issue is to initially deploy Active Traffic Management strategies in regions that already have a traffic management center and along corridors that already are equipped with loop detectors, closed circuit cameras, and dynamic message signs. One way to reduce agency costs while also fostering a regional approach to congestion management would be for multiple jurisdictions to share the cost of installation and operate a joint management center. One center may be able to manage highways over a wide area, as well as arterials and major throughways in multiple adjacent municipalities.

Beyond measures to reduce cost, outreach and education are the most important strategies to enable wider deployment of Active Traffic Management in the United States. Additional case studies, especially those highlighting practices already in place in the U.S. and Canada, can demonstrate to officials that these practices are transferable to the U.S. A cost-benefit analysis showing the relative low cost of operations-based approaches such as Active Traffic Management, as compared with physical capacity expansion, would help sell these strategies to transportation officials, legislators, and the public.

Strategy: B-15. Vehicle Infrastructure Integration (VII)

Description: Building on the Intelligent Vehicle Initiative, the VII initiative seeks to develop and deploy communication technology that will eventually be installed in every automobile in the United States. VII on-board equipment will allow vehicles to automatically communicate with other vehicles and with roadside equipment, exchanging information that would allow the following applications, among others:

- Intersection assistance, such as red light warnings, stop sign warnings, and turning gap assessment;
- Safety warnings such as rapid deceleration ahead, excessive speed through curves, and "in-vehicle signage" alerting drivers to such things as work zones, reduced speed limits, or one-way streets;
- Mobility data transmitted from vehicles to roadside units, providing real-time data to traffic managers for use in signal optimization, traveler information, corridor management, and maintenance management; and
- Convenience and commercial applications such as toll collection, wireless payment services, and remote vehicle diagnostics (possible application to warranty management).

Evidence on Congestion Relief Benefits

VII technology is still in the conceptual development and Proof-of-concept (POC) testing phase. A preliminary "pretesting" benefit-cost analysis conducted by the Volpe National Transportation Systems Center identified 14 "Day One" applications (generally those described in the previous section) of VII, and found that sufficient cost and benefit information currently was available to analyze seven. Among these seven, the preliminary BCA found a B/C ratio of 2.8 over a 40-year analysis period (2010 to 2050). A number of congestion relief benefits were absent from this analysis, which focused primarily on safety elements such as signal violation warnings and "electronic brake lights." However, the analysis did include congestion relief applications such as improved signal timing and ramp metering.

Extent of Current Implementation

VII is still in the conceptual development stage. The Volpe benefit-cost analysis assumed that roadside equipment deployment would occur from 2009 to 2013, with on-board equipment beginning to appear in new vehicles in 2011 and fully phased into new vehicle production by 2013. Full deployment in the national vehicle fleet would take decades, as old vehicles are retired and replaced with new, VII-equipped vehicles.

Research by states, universities, and the private sector is ongoing at sites across the country, with the goal of developing a greater understanding of the myriad of technological issues that must be worked out before widespread deployment of VII is possible. Additionally, the Research and Innovative Technology Administration (RITA) of the U.S. DOT launched the SafeTrip-21 program in December 2007. SafeTrip-21 will advance the VII initiative by launching a series of field tests and other research projects, building on work already completed or underway. The program will be unveiled in November 2008.

Potential Applicability

The overall goal of VII is to reduce congestion, improve safety, and enhance the overall capacity and efficiency of the nation's highway network. This will be accomplished through nationwide deployment of roadside and network infrastructure as well as on-board equipment on all new vehicles. The technology would be expected to enable, at a minimum, the applications listed above, as well as others not yet conceived.

Costs

While many technological issues still need to be worked out, cost and the overall extent of the infrastructure needed for effective implementation are by far the greatest barriers to realization of the VII program. In order to be effective and for its benefits to outweigh the costs, VII technology would need to be widely deployed and a large share of the nationwide fleet would need to be equipped. This would likely require a period of 5 to 10 years of heavy investment before substantial benefits are realized. The costs of this investment would be jointly borne by the government (roadside and network infrastructure) and the private sector/consumer (on-board equipment).

Other Implementation Issues

As noted, many technological issues need to be resolved and research is underway to advance and demonstrate the technology. Institutional issues also pose significant challenges. Cooperation will be required among parties as disparate as automobile manufacturers, state transportation agencies, local public works agencies, and telecommunications providers in order to implement a VII system.

Potential Solutions

U.S. DOT is working closely with the transportation research community and the automotive industry to spread the research burden and ensure that the final product is both effective and cost-effective. The automotive industry is far more likely to support the installation of on-board equipment if the benefits are clearly demonstrated and are marketable to the degree that availability of VII technology would be a contributing factor in consumers' decision to purchase a new vehicle. As such, the public sector investment in infrastructure will need to precede on-board equipment deployment by a number of years. One possible method of phasing in VII and demonstrating its effectiveness and its benefits would be to focus initially on cities, equipping transit buses and, following that, commercial vehicles.

3.9 CATEGORY C – REDUCING DEMAND FOR VEHICLE-TRAVEL

Strategy: C-1. Land Use

Description: Land use patterns to improve travel efficiency and reduce vehicle travel, including infill, mixed-use, higher densities, compact/walkable neighborhoods, transit-oriented development, pedestrian design, and parking management.

Evidence on Congestion Relief Benefits

Land use strategies have been demonstrated to reduce VMT to varying degrees through shorter vehicle trips and by supporting mode-shifting to transit, walk, and bicycle. To some extent, the congestion relief benefits of VMT reduction may be offset by more compact development patterns, which concentrate vehicle-travel in smaller areas and can lead to increased localized congestion. Nevertheless, overall accessibility can be improved (since destinations are closer together), even if travel speeds do not increase.

Land use incentives have limited potential in the near-term (10 to 20 years) to significantly affect VMT, but appear to have more significant potential over the long-term (30 to 50 years). The following summary evidence is available:

- Modeled or measured impacts of site-specific land use strategies, such as infill/redevelopment, transit-oriented development, and pedestrian-oriented design, have ranged from less than 5 to over 50 percent depending upon the nature of the strategy and the context of its application (CS/DOE 2006). Overall, it is estimated that residents of compact development drive approximately 30 percent less than those in traditional development. (ULI 2007)
- A report that compared various metro areas on sprawl indices versus VMT found a significant range, with 27 daily VMT per capita in the 10 most sprawling areas versus 21 in the 10 least sprawling areas (22 percent lower). Households living in developments with twice the density, diversity of uses, accessible destinations, and interconnected streets when compared to low-density sprawl drive about 33 percent less. (Ewing, Pendall, Chen 2002)
- Numerous regional-level modeling studies have been conducted to evaluate alternative land use and transportation scenarios. A review of 23 studies found that compact scenarios averaged 8 percent fewer total miles driven than business-as-usual ones, with a maximum reduction of 32 percent (Bartholomew 2005, cited in ULI 2007). The lower results are typically over a 20 to 25 year time horizon, and longer-term (50-year) studies have found more significant impacts (for example, 25 percent in Sacramento).

- By 2050, changing development patterns nationwide could reduce VMT from passenger vehicles by roughly 7 to 10 percent compared to trend levels. (ULI 2007)

The magnitude of benefits that are achievable depends greatly upon the timeframe of the analysis, due to the long time scales involved in changing development patterns. Benefits are small over a 10- to 15-year time horizon, but increase significantly when viewed over a 30- to 50-year timeframe. Impacts also will vary depending upon the rate of growth (and therefore new development) in a particular region.

Extent of Current Implementation

Over the past decade there has been a notable shift towards more compact development, including redevelopment of inner city neighborhoods, new transit-oriented development, and neighborhoods designed on “neotraditional” or “new urbanist” principles. This has been especially true in larger metro areas with constrained land supply, such as many of the West Coast and Northeast cities. The density of new development – which affects overall trip lengths and therefore VMT – also varies significantly by region of the country based on land constraints. Most new development, however, continues to be largely auto-oriented in nature.

A recent review for FHWA (Bartholomew 2005) identified over 80 metro areas that have undertaken some form of regional transportation/land use scenario planning directed at affecting development patterns, and the number has continued to grow since then. Most of these efforts can be characterized as being in the nascent stages of implementation.

Potential Applicability

Land use patterns are slow to change but may have significant potential in the long-term for affecting travel demand and behavior. For example:

- It is estimated that 89 million new or replaced homes – and 190 billion square feet of new offices, institutions, stores, and other nonresidential buildings – will be constructed through 2050. If that is so, two-thirds of the development on the ground in 2050 will be built between now and then. (Nelson, cited in ULI 2007)
- Because of changing demographics and lifestyle preferences, a significant change in market demand is projected by 2025, with 60 percent of new housing demand being for attached and small-lot residential units. (Nelson, cited in ULI 2007)

Costs

Some studies have suggested that significant infrastructure cost savings can result from more efficient land use patterns, as a result of less road mileage, reduced utility needs, etc. TCRP Report 39 (TCRP 1998) presents results from previous studies suggesting that compact development reduces local road costs about 25 percent compared to "sprawl" development, and utility costs by 20 percent. TCRP Report 74 (TCRP 2000) analyzed the impacts of redirecting 11 percent of new households and 6 percent of jobs out of counties with sprawling conditions; the study estimated that about $110 billion would be saved in local road costs between 2000 and 2025, a 12 percent savings, based on a model of the relationship between population density and lane-mile density. It should be noted that these studies do not necessarily account for offsetting cost increases as a result of greater investment in sidewalks or other public amenities, or for increased construction costs in densely populated areas.

Recent scenario planning efforts also provide insight into the regional costs and cost savings of land use strategies. The Envision Utah project estimated that the northern Utah region would save $4.5 billion in infrastructure costs by the year 2020, compared to baseline or trend conditions; this includes additional costs for public transit but reduced costs for regional and local roadways as well as other infrastructure. The Blueprint Scenario in Sacramento, California is estimated to save roughly $1.5 billion in total transportation capital costs through 2050, or 10 percent of expenditures. The Eastern Planning Initiative in Charlottesville, Virginia estimated that the region could save $0.5 billion in transportation costs by building in a compact, mixed-use style.

Implementing land use strategies bears some public-sector administrative costs as a result of the need to engage in coordinated planning, strategy demonstration, etc. However, these costs have tended to be small compared to the estimated infrastructure cost savings – typically on the order of a few million dollars for planning and implementation activities (exclusive of capital investments). Larger sums have been expended on demonstration projects to "catalyze" or otherwise support "smart growth." For example, the Atlanta Regional Commission's Livable Centers Initiative allocates $350 million over 20 years to supporting infrastructure projects.

Other Implementation Issues

The following barriers are noted to the more widespread coordination of transportation and land use:

- The disconnect between local land use decision-making and regional or state-level transportation decision-making;
- Reluctance of state and regional transportation agencies to become involved in land use planning;
- The market-driven nature of development decisions, which are often difficult for policy to affect;
- Neighborhood/local opposition to higher-density development;

- Lack of coordination of policies and incentives amongst state agencies (e.g., transportation, housing, economic development, environmental), which may lead to such policies working at cross purposes; and
- The fact that locally optimal land use decisions (considering revenue/fiscal, traffic, and other impacts) are often inconsistent with achieving the most efficient land use patterns from a regional perspective.

Potential Solutions

The following strategies have been identified to support coordination of transportation and land use on a more widespread basis:

- State and regional agency leadership, funding, and technical assistance for regional planning and visioning efforts;
- Funding and technical assistance for implementation activities (e.g., area or site plan development, code revision, supportive infrastructure);
- Revision of transportation project selection criteria to reward transportation-efficient land use policies and support investments consistent with regional land use objectives;
- Roadway and transportation facility planning and design practices to support Context Sensitive Solutions;
- Interagency partnerships and agreements (e.g., coordinated plan development, joint review processes); and
- Analysis, education, and outreach regarding the transportation and other benefits of efficient growth patterns.

Strategy: C-2. Road Pricing

Description: Roadway pricing strategies to reduce total demand, including activity center (cordon) pricing, tolling of existing facilities, mileage-based fees, and pay-as-you-drive insurance. (In contrast to strategy B-3, which is intended to *manage* demand by shifting it to less congested periods, the objective of this strategy is to *reduce* overall vehicle-travel.)

Evidence on Congestion Relief Benefits

Pilot studies of mileage-based user fees and pay-as-you-drive insurance have been conducted in Minnesota, Oregon, Texas, and Washington State. Three of these studies suggest that VMT reductions are possible in the range of perhaps 5 to 15 percent for participating travelers, with 10 percent a reasonable midpoint estimate, although the actual impacts will depend upon the magnitude of the fee applied as well as whether the fee varies by time period. In Minnesota, findings indicated that statewide per-mile pricing (converting automobile fixed to variable costs) would result in a reduction in vehicle mileage of 6.6 percent relative to unpriced travel periods on weekdays, and 8.1 percent on weekends

(MNDOT 2006). A pay-as-you-drive study in Texas found that customers rewarded with incentives to drive less drove 8 percent less, on average, than customers in a control group (NCTCOG 2007). In Washington State, estimated elasticities showed that mileage-based user fees could reduce morning peak VMT by 4 percent and afternoon peak VMT by nearly 11 percent (PSRC 2006). Oregon's mileage based user fee experimental program showed even larger results, with a decrease in total miles per day of 13 to 16 percent, although peak-period VMT actually increased if the fee was flat rather than variable (ODOT 2007). A national elasticity-based estimate produced consistent results, suggesting that a pay-as-you drive insurance charge of $0.06/mile could reduce total VMT by 10 percent (NRDC 2006). All of these results, however, apply only to those participating in a mileage-based system. The Minnesota study estimated that only 11 percent of households would participate in a voluntary program; therefore the overall VMT reductions for a voluntary program would be on the order of 1 percent.

Cordon or area pricing has been found to result in a significant reduction in VMT and congestion in the few central city areas to which it has been applied, including London (21 percent less traffic entering the central zone in 2006 than in 2002), Stockholm, as well as modeled reductions of 7 percent if an $8 fee were applied to Manhattan. However, it is not clear how extensive the VMT reductions would be (if any) if applied to other cities that are less congested and less well served by transit, since the concept requires strong transit service to provide viable alternatives to driving. In many U.S. cities cordon or area pricing could have the undesirable effect of reducing economic activity in the central city and thereby increasing overall VMT as development moves elsewhere. Also, in most congested U.S. cities, the heaviest traffic is on the freeway system, rather than on the city streets, meaning that pricing strategies that focus on the freeways may have more impact. With the current state of knowledge it is impossible to make any broad generalizations about the effectiveness of this strategy.

Extent of Current Implementation

No applications of general pricing (i.e., not including individual tolled facilities) have been advanced beyond the pilot stage at this point in the United States. Several have been tried in other countries.

Potential Applicability

Mileage-based fees and/or pay-as-you-drive insurance could conceivably be applied throughout the U.S., if implementation hurdles could be overcome. Those hurdles are considerable.

Costs

The costs of cordon pricing, tolling, and distance-based pricing should be similar to those discussed under strategies B-3 (Congestion Pricing) and A-2 and A-3

(New Toll Roads, Managed Lanes). As previously noted, the variation in costs will be quite significant depending upon the specific strategy applied and existing infrastructure.

Other Implementation Issues

A shift to mileage-based pricing must overcome considerable political and institutional resistance at this point. Some technical issues (e.g., privacy issues related to data collection) also are still being resolved. Pay-as-you-drive insurance may have the greatest potential for near-term implementation as it can benefit a significant number of travelers (i.e., those who would experience lower costs because they drive less than average).

Potential Solutions

Some demonstration projects have been completed or underway to test traveler acceptance of different pricing approaches. It is possible that a successful real-world application in one or more pilot areas could lead to wider acceptance of this strategy.

Strategy: C-3. Freight Demand Management

Description: Truck tolls, lane restrictions, delivery restrictions, intermodal facility, and access improvements to reduce total or peak-period truck traffic and/or shift freight traffic to other modes.

Evidence on Congestion Relief Benefits

TDM strategies addressing freight are often more effective when implemented as part of a larger strategic initiative, considering approaches such as congestion pricing or offpeak delivery incentives that may have adverse impacts on freight shippers.

Evidence from the limited applications of freight TDM strategies has found some benefits:

- In the five years since implementation of London's congestion charging zone (2002 to 2006), total truck trips into the zone declined by 13 percent, while total vehicle kilometers driven inside the zone declined by only 7 percent, suggesting greater productivity per trip. (CS/NYCEDC 2007a)
- After the Port Authority of New York and New Jersey implemented a time-of-day pricing scheme at its six bridges and tunnels between the two states, a survey of New Jersey-based shippers that traveled into New York found that firms representing 20 percent of all total truck trips changed their behavior as a result of increased overall tolls and offpeak value pricing. The most common changes in behavior were increased use of EZPass (which receives a discount) and increased shipping charges. The survey indicated that only 0.5 percent of trips shifted to offpeak hours as a result of the program. A far

greater share increased productivity per trip, thereby reducing the total number of trips (6.2 percent). (Holguín-Veras et al 2005)

- The Offpeak program at the Ports of Los Angeles and Long Beach, which imposes a $100 fee per loaded container during peak-periods, was found to be far more effective than a state law mandating offpeak operation. The nighttime (7 p.m. to 6 a.m.) share of trucks on I-710 increased by over 60 percent eight months after the program started; there were small decreases in truck traffic during a.m. and p.m. peaks, with substantial decreases during the 9 a.m. to 3 p.m. midday period (approximately 15 percent reduction in share of trucks).

Extent of Current Implementation

Strategies to reduce truck traffic have been implemented in a very limited number of situations, primary at major ports or on already-tolled facilities with significant amounts of truck traffic, and with the intent of shifting trips out of peak hours rather than accomplishing significant mode shifting or other methods of truck trip reduction. Strategies such as London's congestion pricing zone and New York City's proposed congestion pricing have been targeted at all forms of traffic, which has included truck traffic.

Many smaller cities and towns have restrictions that limit deliveries only to *daytime* hours out of concern for after-hours noise. There are no known cases of cities in the United States implementing the reverse policy, restricting deliveries to offpeak hours to combat congestion. This also has been studied in New York.

Potential Applicability

- The Red Hook Container Barge concept, in which barge service is used to transport containers to nearby port facilities in order to bypass roadway bottlenecks, may be applicable to other regions with similar highway bottlenecks between adjacent port facilities, such as the San Francisco Bay area and the Seattle-Tacoma-Everett corridor.
- The Port Inland Distribution Network (PIDN), proposed by the Port Authority of New York and New Jersey, aims to both reduce truck trips into the port facilities and also increase the port's market share by arranging reliable container transfer services to nine inland intermodal facilities via rail and barge. This concept could be applicable to other large port complexes across the country.
- With respect to offpeak value pricing, the New York region is unique in that a large volume of trucks originate in New Jersey and must pass through tightly constrained toll bridges and tunnels to reach destinations in New York City. Other regions that lack such well defined physical gateways would likely be better served by London-style congestion pricing zones with offpeak discounting as a means to divert truck traffic to offpeak hours. Such policies could be applied to all traffic or specifically target trucks.

Costs

Some evidence on the cost of these strategies is provided in the discussion of related strategies B-3 (Congestion Pricing) and B-7 (Port Operations).

Other Implementation Issues

Finance and complex administrative arrangements present significant challenges in implementing freight TDM strategies at ports, such as those in place or planned at the ports of New York/New Jersey and Los Angeles/Long Beach. Many port operators have resisted extending gate hours to offpeak-periods out of concern for their inability to recoup the increased labor cost. These strategies also involve a complex web of stakeholders, including port authorities, steamship lines, barge operators, railroads, municipal and regional governments, and numerous trucking companies. The programs are almost always cross-jurisdictional, and government bodies (particularly port authorities that wish to lead an initiative) may be legally prohibited from conducting business outside of their own jurisdiction.

With respect to strategies that aim to move trucking activities to offpeak hours, one of the most commonly cited issues is the fact that trucking companies are frequently at the mercy of their customers. Two studies of the New York region demonstrate this issue:

- The 2005 Holguín-Veras et al. study of the time-of-day variable pricing scheme implemented by the Port Authority of New York and New Jersey at its bridges and tunnels noted that most carriers were unlikely to shift to offpeak hours because the cost to a customer to remain open later just to receive offpeak deliveries would be far greater than the savings realized by taking advantage of offpeak toll rates. Surveys also revealed that many shippers were not even aware of variable pricing.
- A 2007 study by Holguín-Veras used an economic model to demonstrate that peak-period pricing is insufficient to move freight deliveries to offpeak hours, because those costs are fixed (not marginal) and would in most cases not be passed on to customers, and because they pale in comparison to the receiver's incremental cost of remaining open to accept late deliveries. This report suggests that pricing would need to be implemented in conjunction with receiver incentives to receive offpeak deliveries in order to have an effect.

Value pricing as a strategy to divert truck activity to offpeak hours, especially if it is in the form of a peak-period surcharge (rather than an offpeak discount) also is likely to face stiff resistance from shippers and receivers, and may have legitimate negative economic impacts in the form of increased costs of retail goods. Cambridge Systematics' congestion pricing study for the City of New York noted that mandating nighttime delivery for trucks might result in more overall traffic, if some receivers insist on continuing daytime deliveries or if shippers switch to smaller vehicles to skirt restrictions on large trucks.

Potential Solutions

Holguín-Veras recommends that any approach that includes value-pricing offpeak trips be implemented in combination with other strategies, particularly demand-side incentives to induce receivers to accept offpeak deliveries. He also suggests initially focusing offpeak freight initiatives on "large traffic generators" (he cites Madison Square Garden or Grand Central Terminal in New York as examples) where multiple businesses can pool labor resources to accept after-hours deliveries. This principle also would apply to ports, which are certainly large traffic generators. In addition to implementing receiver incentives, outreach to the shipper and receiver communities is crucial as well, in order to understand the concerns of each party, and also to ensure that all are aware of programs and discounts that are available.

When attempting to establish port TDM programs, establishing a cooperative organization to lead and implement the programs is helpful in building the broad consensus among disparate stakeholders necessary to achieve success. Such an organization also may be able to avoid some legal hurdles that prevent municipalities or port authorities from negotiating deals over a large geographic area.

Strategy: C-4. Nonmotorized Improvements

Description: Bicycle and pedestrian improvements, including bike lanes, bike parking, shared-use paths, sidewalks, pedestrian crossings, traffic calming, and pedestrian amenities to encourage nonmotorized travel.

Evidence on Congestion Relief Benefits

The benefits of nonmotorized travel improvements have been difficult to identify in isolation, as most individual projects lead to only very small incremental changes in travel behavior. On the other hand, nonmotorized improvements are a critical complement to land use strategies that aim to create more compact, walkable communities, as well as to transit investments that require pedestrian access. Numerous studies have examined travel behavior in relationship to factors such as street connectivity, mixed-use environment, and pedestrian environment. For example, an evaluation of the Portland, Oregon region found that residents had an average of 9.8 VMT per capita in neighborhoods with good transit and a mixed-use environment, compared to 13.3 in good transit neighborhoods without a mixed-use environment (PBQD 1993). A study in the Puget Sound region found that a fully mixed-use environment was associated with a 20 percent reduction in VMT compared to a fully segregated environment (WSTC 2006). One synthesis suggests an elasticity of VMT with respect to local design factors (including pedestrian design) of -0.03, meaning that a 100 percent increase in the design index would lead to a 3 percent decrease in VMT (Ewing and Cervero 2001).

A few cities with extensive bicycle infrastructure also exhibit very high bicycle mode shares, although these are primarily smaller cities with major universities (e.g., Davis, California, and Madison, Wisconsin). However, differences in bicycle mode shares in larger cities also may be related to differences in bicycle infrastructure. For example, Portland, Oregon has worked extensively to improve bicycling conditions over the past 10 to 15 years, and has seen corresponding increases in levels of bicycling; as of 2007 the city reported the highest bicycle commute mode share (3.5 percent) of the 50 largest U.S. cities (this compares with an average mode share of 0.4 percent nationwide for commuting).[7]

In some cases, pedestrian improvements may be at odds with the goal of congestion reduction. For example, measures to encourage pedestrian travel and improve safety in business districts may result in increased traffic congestion as travel speeds and in some cases roadway capacities are reduced. In such cases, the goal is to maintain alternative routes to support efficient through travel, while sacrificing some local travel capacity for the sake of economic and community vitality and safety.

Extent of Current Implementation

While it is impossible to quantify the extent of such efforts, many cities have recently undertaken initiatives in selected areas to implement pedestrian improvements such as streetscaping, enhanced crossings, and traffic calming in urban business districts, especially to support revitalization efforts. Shared-use off-street paths, such as rail-trail conversions, are being constructed in many states using funding from programs, including the Congestion Mitigation and Air Quality (CMAQ) program and Recreational Trails. According to the Rails to Trails Conservancy, there are approximately 14,000 miles of rail trails open in the U.S., with over 11,000 in the planning stages. Cities, including Chicago, New York City, Philadelphia, Portland, and Seattle, have embarked on major initiatives to become more bicycle-friendly by adding hundreds of miles of on-street bike lanes as well as parking and other amenities.

Potential Applicability

Nonmotorized improvements have the potential to be incorporated into new development, as well as retrofitted to existing development. They are especially applicable in higher-density urban business districts and other locations where destinations are close enough to support significant walking and bicycling. In lower-density and single-use environments they may support recreational activity but are not likely to cause any measurable decrease in vehicle travel.

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[7] http://www.census.gov/Press Release/www/releases/archives/american_community_survey_acs/010230.html.

Costs

Typical costs for pedestrian and bicycle facilities can be as low as a few hundred dollars for painting a crosswalk or $5,000 per mile for signing and striping bike lanes on existing roads. Construction of five-foot sidewalks can be in the range of $200,000 to $800,000 per mile, and traffic calming measures in the range of $5,000 to $20,000 per device. Construction of shared-use paths typically is in the range of $0.5 to $2 million per mile. Structures such as bicycle and pedestrian bridges generally cost at least $1 million, ranging up to $10 million for complex situations.

Other Implementation Issues

Cost is a primary barrier to implementing pedestrian improvements, although other factors (such as emergency vehicle access through traffic-calmed streets and maintenance issues) also can be a concern. Tradeoffs with vehicle throughput and delay also can be a concern for transportation agencies, especially when such improvements are considered on major arterials.

Right-of-way constraints as well as costs can represent a significant barrier to the more widespread deployment of bicycling infrastructure. Local residents often oppose trail construction before it takes place, although the trails are generally popular after they are complete. The availability of corridors for off-street paths is limited, and it may not always be possible to accommodate on-street facilities existing build-up urban environments.

Potential Solutions

Federal funding programs such as Safe Routes to School and CMAQ have encouraged the construction of bicycle and pedestrian infrastructure improvements. Some cities have tapped local and private funds, such as business improvement districts or tax increment financing, for pedestrian improvements.

Creating a high-quality nonmotorized environment in conjunction with new development or new or reconstructed roadway facilities is generally the most cost-effective solution, as improvements can often be implemented at little or no net cost.

Strategy: C-5. Transit Enhancements

Description: Transit capacity or service enhancements to attract new riders including new fixed-guideway service, express/premium bus, new routes, higher frequencies, transit priority operations (bus-only lanes, signal priority, queue jumping), reduced fares, flex service, expanded park-and-ride, and traveler information.

Evidence on Congestion Relief Benefits

The congestion relief benefits of transit enhancements are, in general, highly project- and context-specific as they depend upon the nature of the service improvements, number of new riders attracted, prior mode of travel of these riders, and any offsetting congestion caused by transit operations. Some studies have used elasticities of ridership response to various forms of transit service changes to estimate overall impacts. For example, one recent study suggested that universal transit travel-time reductions and headway increases of 33 percent could lead to a nationwide 1 percent reduction in urban VMT in 2020, increasing to 6 percent in 2050; and that doubling of FTA New Starts program funding for new fixed-guideway service over the 2010 to 2050 period could lead to a 1 percent reduction in total urban VMT in 2030 increasing to 3 percent in 2050 (NRDC 2007). Congestion reductions would likely be more significant than VMT reductions would suggest, since much of the averted VMT would be during peak-periods in larger cities.

One study from the 1970s examined data on changes in VMT for four large cities and six small cities from major bus transit service expansion. Seattle, Miami, Portland (Oregon), and San Diego saw reductions from 4.4 to 14.0 million VMT annually, corresponding to a percentage reduction of 0.06 to 0.25 percent. Smaller cities surveyed saw a mix of decreases and increases in VMT after bus service expansion. (TCRP 95-10)

The Washington DOT 2006 Congestion Relief Analysis modeled the effectiveness of a variety of congestion relief scenarios, including transit expansion, in the Puget Sound region for 2025. Major transit expansion was estimated to reduce overall delay by six percent (WSDOT 2006). An analysis of improvements to two commuter rail lines in the Chicago region suggested that forecast new ridership of 3,000 to 4,200 daily riders could reduce peak-period VMT by three to four percent and travel times by three to seven percent on the adjacent congested freeway corridors. (CS/Metra 2008)

Transit priority operations may have the effect of slightly increasing traffic congestion in specific local circumstances, although by attracting new riders through improved quality of service they also have the potential to reduce overall VMT.

Extent of Current Implementation

Traditional bus transit service has remained at relatively consistent levels in recent years in most cities, although some rapidly growing cities have expanded service considerably to meet population demands. Some areas such as San Diego and Los Angeles also have introduced differentiated services (e.g., express or premium versus local) to target different ridership markets.

Rail transit systems exist in about 30 metro areas in the U.S., of which the majority are of recent construction. A number of metro areas are introducing or expanding their fixed-guideway systems through the Federal New Starts program and/or local sources. Due largely to Federal initiative, bus rapid transit (BRT) is increasingly being implemented or considered as an alternative to rail expansion.

The ITS Deployment Database reports that as of 2004, 29 of 80 metro areas surveyed reported having at least one transit agency with some form of Advanced Traveler Information System (ATIS). Twenty of 95 reported having traffic signal priority capability, covering nine percent of fixed-route buses.

Potential Applicability

The potential for expanding or enhancing transit service is in theory quite extensive but in practicality limited by funding. Transit agencies are revenue-constrained and must focus service where it is most needed for mobility as well as congestion relief purposes. While increasing the amount of transit service provided would take additional personal vehicles off the road, it can be inferred that if the most effective services already have been implemented, expanding service would lead to diminishing marginal returns from a congestion reduction standpoint.

Some strategies such as priority operations and differentiated services may have the potential to enhance ridership disproportionately (relative to costs incurred), compared to traditional service expansion. Such strategies could potentially be implemented on a much more widespread basis. A number of metro areas are proposing the introduction or expansion of rail transit.

Costs

Typical capital costs for new light- and heavy-rail projects are in the hundreds of millions of dollars, with some projects exceeding $1 billion. Smaller scale projects, including BRT and streetcar projects, range in the tens of millions.

Operating costs for fixed-route bus service in U.S. cities average just over $100 per vehicle revenue mile. A typical large city operates in the range of one to two million vehicle revenue miles annually. Therefore, a strategy that involved increasing transit service by 10 percent would cost about $10 to $20 million in annual operating expenses. In addition, capital costs for expanding a fleet of 1,000 buses by 10 percent would be approximately $30 million, assuming a cost of $300,000 per bus.

According to the ITS Unit Costs Database, transit system signal preemption may cost in the range of $5,000 to $20,000 per intersection, plus $500 to $2,000 per bus, placing the cost for a 10-intersection corridor served by a fleet of 10 buses on the order of $100,000. Queue-jump lanes may range from a few thousand dollars for simple restriping and signage, to the tens or hundreds of thousands if pavement and signals are added. The cost of signal preemption and other strategies that improve service efficiency should be offset, at least in part, by reduced operating costs.

Other Implementation Issues

Funding is the primary barrier to expansion of traditional transit service. Major capital investments (i.e., rail and busway), while expensive, often enjoy public support although they may face local opposition over traffic, noise, or other impacts.

Institutional issues (e.g., the need for coordination between transit agencies and local traffic operations units, and lack of familiarity or capacity to deal with new technology) pose barriers to other strategies such as transit priority operations and ATIS.

In many cities, transit suffers from an image problem which may be related to perceived or actual passenger security concerns as well as stigmas associated with using transit.

Potential Solutions

Increasing Federal funding for New Starts or for other forms of transit investment and operations would lead to a direct increase in service provision.

Some areas have attempted to address security/image concerns by implementing premium bus services or fixed-guideway rail. Deployment of security personnel and technology also can help to address problems.

Strategy: C-6. Commuter Choice/Workplace TDM

Description: Programs intended to reduce commuting vehicle travel, including transportation management associations (TMAs), alternative mode information, transit subsidies, ridesharing/ride matching programs and incentives, vanpools, parking pricing or cash-out, telecommuting, alternative work schedules, guaranteed ride home, and worksite bicycle facilities.

Evidence on Congestion Relief Benefits

The benefits of employer-based TDM have generally been modest although not negligible. Experience in the 1990s with areawide employer-based TDM programs has shown that an overall reduction in SOV work trip mode share on the order of 5 percent may be realistic. This translates into VMT impacts for all trips at a regional level of considerably less than 1 percent (FHWA 1999). Similarly, a nationwide extrapolation of the benefits of EPA's Best Workplaces for Commuters program suggested that VMT savings could range from 0.2 to 1.1 percent of total nationwide VMT for all passenger travel. Impacts on congestion would be greater, however, since these VMT reductions would be concentrated in peak-period travel in larger metro areas. (CS/DOE 2006)

The most effective commuter choice strategies are those that provide financial incentives for alternative modes (e.g., subsidized or free transit passes) or disincentives (e.g., parking charges) for driving. SOV use typically declines by up to 20 percent at worksites where a transit benefits program is implemented –

supporting significant reductions in local, peak-period congestion (TCRP 107). Impacts will vary significantly, however, depending upon the availability of travel alternatives for the site or region. Central business districts (CBD) in metro areas with high levels of transit service and significant traffic congestion will see the greatest benefit.

Studies suggest that telecommuting and alternative work schedules have small but still measurable effects on VMT. One study estimated that latent demand for telecommuting could reduce total commuting VMT by 2.4 percent, corresponding to roughly a 0.6 percent reduction in urban VMT (NRDC 2007). Another, focused on Manhattan but based on national data, found that if all of the potential latent demand for telecommuting was realized, between 0.2 and 1.3 percent of commute trips into Manhattan (0.03 to 0.21 percent of all VMT) would be reduced. (CS/NYCMC 2007)

Extent of Current Implementation

EPA's Best Workplaces for Commuters (BWC) program was created in 2002 in order to encourage broader-scale adoption of commuter choice strategies by certifying businesses with qualifying transportation benefits programs (e.g., subsidized transit passes, telecommuting option). As of April 2006, employers representing nearly 3.1 million commuters had been certified. This represents approximately 5.0 percent of the labor force in the 87 metropolitan areas represented by BWC employers, or 2.4 percent of the total U.S. labor force. This program has been discontinued by EPA although its resources continue to be available through the Center for Urban Transportation Research.

In a number of metro areas, regional or local programs exist to provide commuter benefits and/or promote alternative modes of travel. For example, the Metropolitan Washington Council of Governments' Commuter Connections program includes a ridesharing and guaranteed ride home program as well as other informational resources, while the Washington Metropolitan Area Transit Authority (WMATA) facilitates the provision of tax-free transit benefits through its SmarTrip card distribution program.

Potential Applicability

Commuter choice benefits could potentially be provided to the entire metropolitan workforce nationwide, although as noted, the greatest impacts will be realized in CBDs and other activity centers in highly congested areas with good transit service. Typically around 10 percent of a metropolitan area's total employment is located in the CBD.

One study estimated, based on employee survey data from two locations, that telecommuting levels could further increase by 9 to 41 percent compared to existing levels. Perhaps 30 to 40 percent of the workforce is in jobs suitable for telecommuting. (NYCMC 2007b)

Costs

Commuter Choice and Workplace TDM strategies can have a wide range of costs depending upon the specific strategy implemented. A review of the CMAQ program conducted in 2002 identified the following annual costs for sampled CMAQ-funded projects: $100,000 to $1.7 million for five regional ridesharing programs; $1.7 million for a regional vanpooling project in Houston; $170,000 to $3.5 million per year for eight regional TDM outreach/promotion programs; and $20 to $376 million per year for regional employer trip reduction requirements such as California's Regulation XV (TRB 2002). However, the costs of some of these strategies (such as trip reduction requirements) are largely borne by the private sector. A regionwide program of transit subsidies of $30 per month, reaching 10 percent of the workforce, might incur a public-sector cost on the order of $30 million annually for a metropolitan area with a population of two million. However, transit subsidies are simply a transfer of money and not a net cost to society. Travelers also will benefit from reduced vehicle operating costs which may not be included in these estimates. Strategies that directly reduce parking requirements result in cost savings for developers and/or tenants.

Alternative work schedule strategies are virtually costless to implement. For telecommuting, one analysis suggests a cost of $3,000 in one-time costs per employee and $1,000 annually, primarily for equipment and services (equivalent to $150 million one-time and $50 million annually for 10 percent of a workforce of 500,000); however, the same analysis also suggests these costs are far outweighed by improved productivity, office space savings, and other benefits. (Niles 2008)

Other Implementation Issues

A number of factors are responsible for the limited implementation of commuter choice benefits:

- Fiscal incentives (transit subsidies, parking cash-out) are primarily limited by the cost to employers or public agencies of providing these incentives, as well as lack of quality transit service (and therefore employee interest) in many locations.
- Fiscal disincentives (parking charges) are limited by the expectation that parking will be provided free to employees as a benefit, and by the fact that parking supply is not constrained and therefore a market for parking does not exist in most suburban areas.
- Use of alternative modes is limited by employee desires for flexibility (ridesharing, vanpooling, transit) and/or convenience (bicycling, walking). Employers usually have no particular interest in promoting alternative travel options, especially if they are not perceived as desirable to employees.
- Telecommuting and alternative work schedules may be limited at an employer level by concerns about productivity or need for face-to-face

presence, or at an employee level by technological or space constraints for home-based work – many jobs require a full-time presence in the office.

Regional agency leadership (e.g., MPO, transit agency, county, or transportation management association) is required to conduct outreach to encourage businesses to offer benefits to their employees. Such leadership has been stronger in some areas than others.

Potential Solutions

- Many metro areas (through the transit agency, MPO, a TMA, or other entity) have established support services to assist employers with providing benefits and promoting the use of alternative modes. For example, these include systems to automatically distribute monthly transit passes. Reduce-cost transit passes especially provide an incentive for employers to offer this option to their employees.
- EPA's BWC program and some regional programs have attempted to encourage employers to offer benefits by providing technical assistance as well as rewarding them with recognition.
- State and local governments can pass laws requiring that employers over a certain size threshold implement TDM programs. This approach has been taken at a state level in Arizona, California, Oregon, and Washington. Municipalities such as Cambridge, Massachusetts, Durham, North Carolina, Montgomery County, Maryland, and Pasadena, California require TDM commitments as a condition for approval of new development.

3.10 Category D – Reducing Congestion on Transit Vehicles

Two major types of strategies for reducing congestion on transit vehicles are discussed: capacity expansion (taking a variety of forms) and peak-period pricing. In addition, other demand-management strategies focused on reducing overall trips also would have the effect of reducing transit congestion. Examples include flex-time, alternative work schedules, and telecommuting. Nonmotorized improvements also could have the effect of shifting some trips from transit.

Strategy: D-1. Transit Capacity Expansion

Description: Capacity expansion may come in a number of forms. One is to increase the frequency of service on existing bus or rail lines. Capacity also can be expanded by using larger buses, expanding physical capacity of a rail line through platform extensions or additional trackage, adding limited-stop service to bus routes, or constructing and operating entirely new bus or rail lines. The capacity of existing vehicles also may be increased by removing and/or reconfiguring seating, to allow more room for standees.

The Transit Capacity Expansion strategy is similar to Strategy C-5, but the discussion focuses on the benefits with respect to reducing congestion on transit vehicles rather than highway congestion.

Evidence on Congestion Relief Benefits

Increasing capacity along any well-used transit corridor is likely to result in an increase in ridership as some latent demand is satisfied. However, the elasticity of demand with respect to capacity is likely to be well below 1.0, suggesting that increasing capacity results in a net decline in vehicle crowding.

In TCRP Report 95, Chapter 9, the authors found that ridership elasticity with respect to frequency improvements rarely exceeds 1.0, and that marginal increases in ridership are lowest in corridors where frequent service already exists. The study generally found an elasticity of around 0.3 for "central city urban systems."

Extent of Current Implementation

Some transit capacity expansion has come in recent years through the addition of new rail or bus rapid transit (BRT) lines in certain cities. Some rapidly growing cities in the south and west, such as Las Vegas, have added new bus lines and increased frequencies on some routes to keep up with the growth in demand in these areas. In most areas, however, Federal, state, and local funding sources for transit operations have remained relatively constant and have constrained the ability to increase capacities. As fuel prices rise, in fact, some agencies may need to decrease service if supplemental funding sources cannot be found.

Potential Applicability

Almost any transit system could conceivably expand service capacity. Some rail systems, however, are constrained in their ability to do so without major capital investment, due to physical and operational constraints (e.g., station platforms of fixed length, minimum headway requirements in core tunnels).

Costs

Costs for transit service expansion, including increasing frequencies and constructing new bus or rail lines, are described under Transit Enhancements (Strategy C-5).

Purchasing articulated buses costs roughly $500,000 per bus compared to $300,000 for standard buses, and also will incur some additional fuel costs as well as potential running time penalties that may partially offset the capacity benefits of the larger bus. According to 2006 American Public Transportation Association data, LRT vehicles cost $2.3 to $2.7 million, heavy rail vehicles $1.2 to $1.4 million, and commuter rail vehicles $2.1 to $2.3 million.

Other Implementation Issues

Cost is the single biggest constraint to service expansion in most cases. Nearly all transit agencies depend on state and Federal operating and capital assistance, and these funds are scarce. If ridership elasticity with respect to service expansion is less than 1.0, then unless fare changes are implemented at the same time, this would result in a decline in farebox recovery.

There also may be political hurdles if expansion in one area is proposed at the expense of contracting or eliminating service in another.

Removing seating to allow more room for standees may not be well received as fewer customers will be able to sit. This is especially a concern on longer trips.

Potential Solutions

Operational improvements, such as signal pre-emption or "queue jump" lanes, could potentially allow service frequencies to be increased without purchasing additional vehicles or incurring additional operating expenses, by reducing run times.

"Jump seats" that fold up when not in use may allow for a compromise whereby standee capacity is maximized during peak-periods, while offpeak travelers have more seating options.

Strategy: D-2. Transit Peak-Period Pricing

Description: Peak-period transit pricing refers to the establishment of variable fares, whereby peak-period travelers pay more than offpeak. The idea of peak-period pricing, similar to congestion- or value-pricing of automobile travel, is to encourage users to shift from periods where the system is at or near capacity to periods where there is excess capacity.

Evidence on Congestion Relief Benefits

A number of studies have examined the elasticity of transit ridership with respect to fares. Some studies also have attempted to identify the cross elasticities of peak-period demand with respect to offpeak fares, and vice versa, to ascertain whether fare changes are pushing people on and off of transit entirely, or accomplishing the goal of shifting ridership to offpeak-periods and thus smoothing the peaks and valleys of ridership over the course of the day.

The most common and often cited finding of these studies is that peak-period ridership is only about one-half as elastic as offpeak, regardless of city size or transit mode. This is logical as the significant swell of ridership during peak-periods is principally comprised of commuters who are constrained by fairly rigid work hours.

TCRP Report 95 Chapter 12 found that cross elasticities are quite small, generally under 0.15. Cervero (1990) found similarly modest cross elasticities. This suggests that in cases where offpeak fares are reduced, most of the increase in ridership represents new transit trips, and implies that in order to affect a major shift in peak-to-offpeak ridership patterns, it is probably necessary to both increase peak fares *and* decrease offpeak fares, maximizing the disparity between them.

Extent of Current Implementation

The Washington Metropolitan Area Transit Authority (WMATA), serving the Washington, D.C. area, is the largest transit authority in the nation to impose peak-period pricing. In New York, commuter trains have differential peak and offpeak fares, and the Metropolitan Transportation Authority (MTA) currently is considering a similar fare structure on the city's subway system. The Chicago Transit Authority (CTA) has proposed peak pricing several times in the past few years, generally during budget crises, but has not implemented such a system.

Other transit agencies with some kind of peak-period pricing system include King County Transit in Seattle, the Southeastern Pennsylvania Transit Authority (SEPTA) in the Philadelphia region, Metro Transit in Minneapolis-St. Paul, and New Jersey Transit.

Potential Applicability

As a method for reducing peak-period transit congestion, differential pricing would be applicable on any system and along any line where rush hour congestion is a problem. Most transit agencies have transitioned to some form of electronic fare collection in addition to accepting cash, making the technical challenges minimal.

Higher fares during peak-periods also might be applicable in conjunction with capacity expansion, by offering "premium" service with limited stops and faster travel times during rush periods, and charging a higher fare for such services.

Costs

The actual implementation costs of differential fares would be minimal, and consist mainly of studying the ridership and revenue implications, informing the public of upcoming changes in fare policy, and reprogramming fare collection equipment.

The larger implication with respect to cost is how a change in fare structure would affect ridership and, by extension, revenue. Since most studies found elasticities to be less than 1.0 (positive elasticity reflecting the *decrease* in ridership associated with a fare increase), this implies that total revenue would increase.

Other Implementation Issues

Raising peak fares may prove to be unpopular with regular commuters who are unable to shift their schedules to offpeak-periods to take advantage of savings. If the agency is planning to raise fares anyway, and simply chooses to do so differentially, this may be less of a problem. Marketing a policy as "offpeak discounts" rather than "peak-period surcharges" also can help to make it more palatable.

Potential Solutions

One group that was found to be far more responsive to peak-period pricing is senior citizens. Federally supported transit agencies are required to offer discounts to seniors, but may choose to waive these discounts during rush periods. Studies of fare changes in several cities indicate that the elasticity of peak ridership with respect to offpeak discounts is at least twice as high for seniors as for the general population, but still fairly low (less than 0.4).

4.0 Case Studies

4.1 Introduction

This section summarizes case studies of congestion management practices in four metropolitan areas: Dallas-Fort Worth, Texas; Minneapolis-St. Paul, Minnesota; Orlando, Florida; and San Diego, California. Detailed case studies are included as Appendices to this report. These areas were selected as having "leading-edge" congestion management practices that effectively support congestion reduction. To select the case studies, recent literature on congestion management approaches was reviewed, including findings of congestion management workshops and peer exchanges sponsored by the Federal Highway Administration (FHWA) and American Association of State Highway and Transportation Officials (AASHTO), as well as other FHWA reports and information on regional agencies' web sites. The objective of the case studies was to document these areas' activities in more depth, by conducting site visits and telephone interviews with local agencies to discuss activities, success factors, and lessons learned. The case studies focus primarily on system operations and demand management strategies, but also identify innovative approaches to financing and constructing capacity expansion where it is needed.

A significant question underlying these case studies is whether some metropolitan areas have been especially successful in managing congestion and maintaining mobility for passenger and freight travel; and if so, what lessons can be learned from their efforts. Aggregate measures of congestion at the metropolitan area level are available from Texas Transportation Institute (TTI) research, as shown in Table 4.1. However, the study team did not feel comfortable using this data to say that one area is doing a particularly good job relative to other areas. Congestion can be managed through capacity expansion, system operational improvements, and demand management, but also is affected by other factors beyond the control of transportation agencies, such as total population and population growth (also shown in Table 4.1), economic activity, and physical/topographic characteristics. Even those agencies that have shown the most creativity in developing alliances to overcome institutional and political constraints must still work within certain limits. Therefore, the intent of these case studies is to showcase some examples of agencies working to manage congestion as best they are able, given the unique set of local constraints that they face.

Table 4.1 Comparison of Metropolitan Area Congestion and Population Statistics (2005) [a]

	Rank					
Metropolitan Area	Annual Delay per Traveler, Hours	Increase in Delay, 1982-2005, Hours	Travel Time Index[b]	Operational Treatment Savings, 1,000 Hours of Delay[c]	2005 Population, Millions	2000-2005 Population Change
Dallas-Fort Worth-Arlington, Texas	58 (5)	48 (1)	1.35 (9)	12,193 (6)	5.8 (4)	11.7% (68)
Minneapolis-St. Paul, Minnesota	43 (23)	37 (5)	1.26 (26)	5,367 (14)	3.1 (16)	5.2% (250)
Orlando, Florida	54 (8)	36 (7)	1.30 (17)	1,929 (25)	1.9 (27)	17.1% (22)
San Diego, California	57 (6)	45 (2)	1.40 (4)	7,949 (10)	2.9 (17)	4.1% (325)

[a] All data are for 2005 unless indicated. "Rank" is ranking among metropolitan areas nationwide. Data sources: Texas Transportation Institute, the 2007 Urban Mobility Monitoring Report; and U.S. Bureau of the Census Population Estimates (July 1 of each year).

[b] Travel-time index: The ratio of travel time in the peak-period to the travel time at free-flow conditions.

[c] Operational treatment savings: Estimated benefits of freeway incident management, freeway ramp metering, arterial street signal coordination, arterial street access management, and high-occupancy vehicle lanes, based on deployment statistics collected by U.S. DOT.

Each case study addresses the following topics:

- The planning process, including consideration of congestion relief in developing programs and selecting projects;
- Congestion management approaches;
- Performance measures, monitoring, and evaluation;
- Partnerships supporting effective congestion management; and
- Funding for congestion relief projects and programs.

The case studies reference the Federally mandated congestion management process (CMP) that each region's metropolitan planning organization (MPO) must develop, as most recently defined under the 1998 Transportation Equity Act for the 21st Century (TEA 21) and continued under the 2005 reauthorization bill. The best regional examples have integrated congestion management throughout their planning and programming process. The U.S. Department of Transportation (DOT) defines the following objectives for a congestion management process:

- Measuring multimodal transportation system performance;
- Identifying the causes of congestion;
- Assessing alternative actions;

- Implementing cost-effective actions; and
- Evaluating the effectiveness of implemented actions.

While the MPO is generally the lead agency from a planning perspective, other agencies also play a significant role in congestion management, including the state department of transportation (DOT), transit operators, toll authorities, and local jurisdictions. Their involvement includes facility construction and operations as well as participation in congestion management planning activities. The case studies highlight examples of successful working relationships among these agencies to support strategy implementation as well as data collection and performance monitoring.

4.2 NOTEWORTHY FINDINGS

As anticipated, each case study identified noteworthy practices that appear to have led to effective implementation of congestion management practices. In some cases, "success" has been documented through quantitative measures of congestion relief. In others, it is measured through qualitative assessment of local stakeholders that the process is working and beneficial projects are being implemented. Some of the most innovative and successful examples of practice uncovered in these case studies are highlighted below.

In the **Dallas-Fort Worth** region, the North Central Texas Council of Governments (NCTCOG) has focused efforts on **low-cost intersection and traffic signal improvements** along arterials through its Thoroughfare Assessment Program. NCTCOG works on this endeavor with several city governments as well as the Texas DOT. Approximately 300 arterial intersection improvements and 1,000 traffic signal improvements are funded in the current Transportation Improvement Program (TIP). Significant benefits have been quantified from past projects, including a 16 to 31 percent decrease in travel time and a 39 to 67 percent decrease in delay along improved corridors. NCTCOG and local transit agencies also have focused on **promoting alternative modes**. A web-based educational program enables the public to record information about their alternative commutes and offers gift-card incentives; since the program began in October 2006, the web site has recorded over 753,000 miles of alternative commute modes. The Fort Worth Transportation Authority implemented an innovative marketing campaign targeting choice commuters that was credited with helping to boost transit ridership by about 10 percent. To **communicate** congestion issues to the public and build support for congestion management, NCTCOG has developed innovative ways of illustrating congestion, including regional "blob maps" showing areas of light, moderate, and heavy congestion, and aerial photographs to illustrate temporal and spatial patterns of congestion. Finally, new capacity in the region is being added almost exclusively through **tolling and managed lanes**, and TxDOT has developed Tolling Service Agreements to allow it to efficiently enter into partnerships with private entities to construct and operate toll facilities.

The **Minneapolis-St. Paul** region is known for its comprehensive **freeway ramp metering** system. First implemented in the 1970s, this system was initially credited with maintaining peak-period freeway speeds even in the face of increasing volumes; a comprehensive review in 2000 showed that the system continues to produce significant benefits to the traveling public. The ramp metering system also is one component of a larger strategy to **give transit a travel-time advantage** in peak-periods, through the use of high-occupancy vehicle (HOV) queue bypass lanes on the ramps, an extensive network of bus-only shoulders, direct access from park-and-ride lots, and transit signal prioritization. The region's MPO, the Metropolitan Council, is also its primary transit operator and the agency has worked closely with the Minnesota DOT and local agencies through "Team Transit" to implement these transit-supportive operational strategies. A recently awarded **Urban Partnership Agreement** with the U.S. DOT will demonstrate new initiatives, including dynamically priced shoulder lanes, parking and transit information, bus rapid transit (BRT) expansion, public-private telecommuting initiatives. The region also is undertaking a Federally funded pilot deployment of **integrated corridor management**, using ITS technologies to coordinate highway and transit information and operations along arterial roadways.

In **Orlando**, Metroplan Orlando, the MPO, has focused especially on nonrecurring congestion. Metroplan has formed partnerships and entered into agreements with other regional, state, and local agencies to implement **incident management practices** to minimize delay. Examples include the Tri-County Area Open Roads Policy, an agreement among state and regional transportation agencies, emergency response authorities, and local jurisdictions to clear all incidents from the roadway within 90 minutes after the arrival of the first responding officer; and the "MOVE IT…Yes You Can!" campaign to inform motorists of the need to move vehicles out of the travel lanes if they are involved in a minor traffic accident. The Florida DOT (FDOT) has established Traffic Incident Management (TIM) teams comprised of representatives from all of the responding agencies and service providers in a particular FDOT District, who review past response actions and explore ways that incident management can be improved. Metroplan and FDOT also have focused on **traffic signal coordination**, gaining agreement of all local agencies to use FDOT signal phasing standards and implementing computer-coordinated traffic signal systems along major corridors, covering 67 percent of the region's signals as of 2007.

In **San Diego**, the San Diego Association of Governments (SANDAG) has worked to aggressively implement **travel demand management** strategies in the region, in addition to traffic operations and capacity expansion. SANDAG conducts outreach and technical assistance to assist employers in promoting alternative mode use and alternative work schedules among their employees, as well as offering regional ridematching, vanpooling, and guaranteed ride home programs. The vanpool program currently operates 500 vanpools and is credited with reducing nearly 114 million vehicle miles of travel in 2007. On the operations side, SANDAG was a pioneer in implementing **high-occupancy/toll (HOT) lanes** to improve freeway throughput while still maintaining travel-time benefits for HOVs; HOT lanes on I-15 move 21 percent more people per lane in the p.m. peak-period than the general purpose lanes. Work is underway to expand the HOT lane network. SANDAG and the California Department of Transportation (Caltrans) also have worked cooperatively on implementing **regional ITS** for data collection, performance monitoring, and traffic management, including a pilot integrated corridor management application working in partnership with local transit agencies and the California Highway Patrol. The statewide Freeway Performance Monitoring System (PeMS) collects comprehensive data on freeway volume and lane occupancy, and provides the ability to estimate various performance indicators through a web-based application. SANDAG has recently begun using PeMS data for monitoring in support of the Regional Comprehensive Plan. Finally, SANDAG has successfully maintained voter support for **transportation funding sources**, most notably TransNet; a half-cent local sales tax first established two decades ago that provides funding for both system expansion and system management.

4.3 CONCLUSIONS

From these case studies, a few common themes emerge regarding how to effectively manage congestion:

- **Congestion management is not just individual technical solutions – it is an overall approach.** This approach includes (perhaps among other things) engineering technologies, information infrastructure, data and analysis, funding, public involvement, partnerships, and outreach. The most effective congestion management efforts include all of these elements. For example, public outreach strategies are necessary to build support for effective strategies and for obtaining funding for these strategies. Many effective strategies cannot be fully implemented without supportive information infrastructure.
- **Strong working partnerships are critical.** Congestion problems transcend political and institutional boundaries. Dallas-Fort Worth and Orlando illustrate how actions such as coordinating traffic signals, implementing low-cost capital improvements, and responding to incidents require coordination among regional, state, and local entities. San Diego illustrates how partnerships can effectively support data collection and performance monitoring as well as travel demand management. The Team Transit initiative in Minneapolis-St. Paul illustrates an effective partnership for improving transit operations.
- **Effective congestion management goes beyond capacity expansion**. The agencies examined in these case studies have been at the forefront of implementing innovative operational and management strategies and helping to demonstrate their benefits so that they can become part of the mainstream. Some of these are "tried and true" strategies (such as ramp

metering, corridor-level traffic signal coordination, and incident management), while others are innovative and relatively unproven (such as integrated corridor management).

- **Collection of quality data** is important for supporting problem identification, strategy analysis, and performance monitoring. Before-and-after studies can illustrate which strategies are most effective. In Orlando, FDOT documented how changing the number of dedicated highway patrols affected the timeliness of incident clearing on congested freeways. In Minneapolis-St. Paul, the temporary suspension of ramp metering by the state legislature provided the opportunity to demonstrate the positive impact of ramp metering on traffic flow and congestion. Agencies in all the case study regions have taken steps to integrate and expand data collection and monitoring efforts, but also note that there is much that remains to be done in this area.

- **Communication with the public** is critical for building and maintaining support for key programs. The Dallas-Fort Worth MPO notes that its techniques to communicate existing and future congestion problems via maps and other graphics have helped build public support for regional transportation plan initiatives. SANDAG's outreach has been a key factor in maintaining public support for regional funding sources. The "Move It…Yes You Can" initiative in Orlando helps educate the public on how their behavior affects congestion and mobility in that region.

5.0 Keys to Implementing Effective Strategies for Congestion Management

This section reviews findings from the literature on the effective implementation of congestion management practices, building upon and extending the case study findings. Much of this literature responds to the provision contained in the 2005 SAFETEA-LU surface transportation reauthorization legislation that the transportation planning process for urban areas having a population of more than 200,000 persons, designated as Transportation Management Areas (TMAs), shall address congestion management through a *congestion management process* (CMP). The CMP is to be a cooperatively developed and implemented metropolitan-wide strategy that 1) measures multimodal transportation system performance for both person travel and goods movement; 2) identifies the causes of congestion; 3) assesses alternative actions; 4) implements cost-effective solutions; and 5) evaluates the effectiveness of implemented actions. A congestion management process, thus, builds upon but also represents an important extension of a congestion management system (CMS).

The literature compiled since the passage of SAFETEA-LU has included case studies and documentation of workshops sponsored by FHWA and AASHTO on statewide and metropolitan congestion management, as well as other research such as that conducted for FHWA's Statewide Reference for Linking Planning and Operations. Based on the information collected and reviewed for this project, the following are keys to successfully implementing effective strategies for congestion management.

1. *Emphasize a congestion management process (CMP) rather than only a congestion management system (CMS); treat the CMP as an objective-driven, performance-based strategic approach for addressing congestion.*

   Building on input provided by the Atlanta, Detroit, Kansas City, Hampton Roads, Wilmington, Pittsburgh, and Northern New Jersey urban areas and the Pennsylvania, Oregon, and Rhode Island DOTs, the FHWA produced a February 2008 Interim Guidebook on the Congestion Management Process in Metropolitan Transportation Planning. It was agreed that a CMP "is as much a way of thinking about congestion-related issues as it is a set of technical tools." An eight-step process is envisioned,[8]: 1) develop congestion

[8] Illustrated in Figure 1 on Page 2-7 of FHWA's an Interim Guidebook on the Congestion Management Process in Metropolitan Transportation Planning, 2008.

management objectives; 2) identify areas of application; 3) define the system or network of interest; 4) develop performance measures; 5) institute a system performance monitoring plan; 6) identify and evaluate alternative strategies; 7) implement selected strategies; and 8) monitor the effectiveness of implemented strategies.

2. *Congestion management often requires investments at critical bottlenecks or choke points.*

   As defined in AASHTO's September 2007 Combating Congestion through Leadership, Innovation, and Resources, bottlenecks are critical choke points in a transportation network and often have far-reaching impacts on network efficiency. The 2004 American Highway Users Alliance study estimated that bottlenecks account for about 50 percent of driver delays. The Minnesota DOT is one of several states that have developed targeted investment programs aimed at eliminating bottlenecks. A four-month Congestion Management Planning Study (CMPS) was undertaken in 2007 to identify low-cost congestion relief projects that could be implemented very quickly. The study was designed to "tune" rather than rebuild the system. They found that the resulting projects proved to be both highly visible and popular with the public. They also found that the projects could be "spread around" in a fair and equitable manner.

   Effective congestion management, at the same time, should be undertaken based on the development and implementation of integrated corridor and regional congestion management strategies. Transportation systems consist of highly connected networks. Addressing a problem at one location easily can have spill over effects elsewhere. Consequently, it is important to systematically address congestion on a corridor, subarea, and areawide basis, including the coordinated operation of freeways and major arterial roads. As described in the case studies, integrated corridor management approaches are being introduced in the congestion management process for the Minneapolis-St. Paul and the San Diego metropolitan areas.

3. *Congestion management should be approached on a multimodal basis and coordinated with incident management, emergency services, traffic operations planning, access management, maintenance strategies, and the investment in new capacity.*

   An effective congestion management process includes, but is not limited to, traffic operational strategies. ITS technologies are an integral component as are demand management measures, growth management, public transportation improvements, and additional system capacity where this proves to be necessary. Each of the four case studies undertaken for this project provides an illustration of this approach. The North Jersey Transportation Planning Authority (NJTPA) is an additional example of a MPO that has taken a multimodal approach to congestion management planning, with particular attention given to the role of public transportation.

The NJTPA region consists of 13 northern New Jersey counties. These contain two major cities, Newark and Jersey City, and a population of 6.5 million people. The NJTPA congestion management strategy addresses accessibility and mobility in addition to congestion. Four of the eight performance measures are multimodal and address mobility by highway, transit, and bike/walk. Twenty-four types of strategies were developed, one-third of which related to transit.

4. *Identify and program separate congestion management funding sources.*

   Funding available for congestion relief, traffic operations, and operations-related maintenance is not sufficient to meet needs. CMAQ represents one potential funding source. ITS funding represents another valuable source. One programming technique is to allocate a specified percentage of available funds for congestion management, and then establish priorities within this category. Between 1993 and 2006, the Hampton Roads Planning District Commission (HRPDC) in Virginia utilized 62 percent of their CMAQ funding for signal system integration, intersection geometric improvements, and ITS projects, with the remaining 38 percent used for bikeway/pedestrian, new transit service, bus replacement, and TDM projects. An additional $150 million in their long-range plan was allocated for ITS/operations. Surface Transportation Project (STP) money also has been used to fund ITS/ operations. The San Diego metropolitan area utilizes a half-cent local sales tax, referred to as TransNet, as a local revenue source to support its congestion management efforts.

5. *Pricing is an important tool that can be used to manage the timing and magnitude of travel demand, and serves as one potential source for funding the implementation of congestion management strategies.*

   Instrumented vehicle technology is creating opportunities for new ways of pricing travel and collecting tolls. Many of the participants in AASHTO's 2007 National Congestion Summits believed that pricing strategies represent some of the most important tools that can be used to manage the demand for travel, and thus congestion levels. High-Occupancy Toll (HOT) Lanes have been implemented in San Diego, Orange County, Denver, Houston, and Minneapolis. Other proposals involve cordon pricing similar to approaches implemented in London, Stockholm, and elsewhere. Still others involve changes in the way parking is priced, the use of pay-as-you-drive vehicle insurance, and a mileage-based VMT fee.

6. *Stakeholder involvement is critical for effective congestion management, including businesses whose economic competitiveness is dependent on the operation of reliable and efficient transportation systems.*

   A high level of cooperation among the full range of public and private stakeholders is an important element of a congestion management process, just as it is in the broader transportation planning and project development process. As illustrated in the four case studies, it is beneficial to bring to the table and actively engage the full range of appropriate stakeholders throughout a CMP, beginning with the earliest steps. The San Diego Association of Governments (SANDAG) believes that all congestion management initiatives should be undertaken on a collaborative basis, and that it is beneficial to work with various partners in all stages of a project. Good communications materials and forums are important to moving congestion management programs forward. NJTPA regularly utilizes stakeholder advisory committees. NCTCOG includes local agencies, the airport, the toll authority, and three transit agencies, including the nurturing of champions that will actively support adopted programs. Stakeholder involvement, as demonstrated by the Orlando case study, increasingly is being extended to include incident management teams, emergency medical first responders, and maintenance personnel.

7. *Data availability has a significant influence on what can be accomplished.*

   Freight as well as person travel-related data are needed. Data are required not only to support analytical methods but also to communicate the nature of congestion problems to decision-makers and the public. Basic steps of a congestion management process include the monitoring of system performance and strategy effectiveness. Further, a congestion management process is to be performance-based, meaning that a set of performance measure metrics should be used to track the performance of the transportation system over time.

   While these data needs have long been recognized, participants in FHWA's national workshops on congestion management consistently reported that the availability of data historically has been one of the largest challenges faced by organizations in developing effective congestion management strategies.

   The introduction of automated traffic data collection systems combined with the use of ITS-based systems for archiving, accessing, and using these data is resulting in important advances in the full range of data-related needs. These advances include the use of visualization tools to help translate data into forms that are easily understandable to the full range of stakeholders and decision-makers. Staff of the Washington State DOT are trained in the retrieval and analysis of ITS collected freeway data. NCTCOG utilizes low-level aerial photos in combination with traffic counting stations. SEMCOG obtains information from the county's system of 600 adaptive traffic signals. The Hampton Roads Planning District Commission uses roadway segment travel volumes collected at 15-minute intervals in combination with travel time/speed runs and Highway Capacity Manual methods to calculate segment and lane-based level-of-service performance measures. This system is supported by a regional smart traffic center that is tied into locality-specific smart traffic centers; these centers provide public information about travel conditions as well as serving as a communications backbone for operations planning and coordinating incident management and real-time responses.

8. *Document and communicate the benefits of congestion management.*

   With limited funds, many states reported in AASHTO's National Congestion Summits that they have found that monitoring and measuring system performance is key to allocating congestion management resources in a cost-effective way. Data can help identify where additional investments in congestion management should be made geographically, and what strategies should be deployed. This includes programmatic-level reporting, such as that represented by Washington DOT's *Gray Notebook*; corridor and facility-level reporting; and the monitoring results of deployed strategies. Many MPOs utilize "state of the system" reports such as Orlando's "Tracking the Trends," the Minneapolis-St. Paul region's four-year "Transportation Audit," and the NCTCOG "Transportation: State of the Region" annual report. These are used as a report card for effectively reporting on congestion management to a broad audience.

   NCTCOG has a policy that before capacity is added, their policy board needs to first be provided with documentation of what other measures have been considered and either already have been implemented or will be implemented in association with the added capacity. The Puget Sound Regional Council (PSRC) frames the communication of congestion issues in terms of all travel modes. The "boomerang chart" is used by PSRC to communicate the relationship between speed and flow deterioration. This chart illustrates how increasing traffic volumes eventually results in decreased vehicle throughput.

9. *Evaluate and prioritize candidate congestion management strategies, consistent with other transportation system management and investment opportunities.*

   The framework for a congestion management process parallels that of the broader metropolitan area and statewide transportation planning processes. Building upon a set of objectives and identified performance-based needs, alternative solutions are identified, evaluated, and prioritized. Agencies have found that it is helpful in developing and implementing congestion management strategies to follow a process that stakeholders already are largely familiar with. Further, coordinating the development of congestion management strategies with the larger transportation plan and program helps in getting congestion management strategies adopted, programmed, and implemented since such strategies are explicitly designed to support more capital intensive capacity expansion projects. In prioritizing projects eligible for CMAQ funding, the Minneapolis-St. Paul Metropolitan Council assigns extra points where it can be demonstrated that a project will reduce roadway congestion. The Council reports that approximately one-quarter of possible points in the scoring process accrue from direct congestion mitigation benefits.

   Considerable effort is going into the development of improved analytical tools that will be useful in evaluating the effectiveness of congestion management strategies. Sketch planning tools can be helpful in the early stages. More detailed analytical tools include the use, often in combination, of travel demand models, Highway Capacity Manual based deterministic methods, traffic signal optimization models, macroscopic simulation models, and microscopic models that simulate the movement of individual vehicles. Effort currently is being given to the development of mesoscale models that combine characteristics of both macroscopic and microscopic simulation.

SEMCOG uses a three-step evaluation/prioritizing process. The first utilizes link-level quantitative analysis techniques to evaluate candidate strategies. The second obtains input and feedback from stakeholder groups and regional partners. In the third, the resulting information is used to combine individual congestion relief measures into larger corridor-level projects.

10. *Include congestion management strategies as an element in metropolitan area and statewide long-range transportation plans and in corridor plans, ensuring that projects are consistent with one another.*

MPOs historically developed long-range plans with a 20- to 25-year time horizon and a focus on capital investments. In contrast, metropolitan transportation plans increasingly are now providing a mix of long-term capital investment and both long-term and near-term operational enhancements to the regional transportation system. Congestion management strategies can be used to reduce the amount of added capacity that otherwise would be required. Further, transportation agencies have found that a combination of practicality and funding limitations often work against adding the desired amount of roadway capacity through either widening or the construction of entirely new facilities that are sufficient to meet projected future demand. As a result, metropolitan transportation plans include operational and management strategies that are designed to improve congestion, mobility, and safety. Congestion management strategies also help to coordinate long-range transportation plans with transportation improvement programs and corridor plans. The results of the congestion management planning process can be documented as part of a regional transportation plan or incorporated by reference. As stated in FHWA's February 2008 Interim Guidebook, discussion of the CMP and its outputs provides a bridge between the transportation challenges currently facing residents and the proposals for projects that will be accomplished over a longer time horizon.

As described in the case study for the Dallas-Fort Worth metropolitan area, NCTCOG has fully integrated the CMP into the region's planning and programming processes so as to ensure that congestion management is a central element of the long-range plan, corridor studies, the Transportation Improvement Program, and the Unified Planning Work Program. In Orlando, considerations of congestion management were integrated into that region's "How Shall We Grow?" visioning initiative. It was recognized that the combination of continued rapid growth and almost certain constrained transportation funding could seriously threaten the livability and economy of the region if issues associated with transportation, land use, the economy, and the environment were not addressed in a coordinated manner.

The Southern California Association of Governments (SCAG) is another example of an urban area where congestion management strategies are fully integrated into the regional transportation planning process. In the SCAG region, the Los Angeles, Orange, Riverside, San Bernardino, and Ventura counties are contained within the transportation management area. The region's overall congestion management process consists of the following three elements: the regional transportation plan; congestion management programs for each of the individual counties; and the regional transportation improvement program. By state statute, each county-level congestion management program includes a consistent set of functions, although the specific form and procedures may vary by county. All Federally funded congestion relief strategies are programmed into the regional transportation improvement program, and all county congestion management projects must be incorporated into the RTP in order to receive state as well as Federal funds. The result is that county-level congestion management programs are brought together in an integrated and consistent fashion as part of SCAG's regional transportation planning process.

11. *Implementation of congestion management strategies through a systematic congestion management process has the potential to contribute to important environmental objectives, including supporting the NEPA process.*

Since the deployment of congestion management strategies results in improving the operating efficiency of transportation systems, such strategies have the potential – along with vehicle technology, low-carbon fuels, and travel demand management strategies – to reduce emissions from motor vehicles, including greenhouse gases. Congestion management strategies, therefore, are being incorporated into state and local climate change action plans, with California being only one example.

Transportation officials also are beginning to view congestion management in the context of broader sustainability objectives. In addition to fuel consumption and air pollution, these include maintaining desired levels of mobility and supporting economic activity. Performance measures for the San Diego region include measures of sustainability that were updated by SANDAG in 2007 to improve the manner in which congestion is evaluated, converting to a per capita basis for characterizing daily vehicle miles of travel.

A congestion management process also can help support the NEPA process, helping to link operations planning with NEPA, helping to shape the purpose and need for transportation improvements, serving as a preliminary screening of alternatives, and providing input to environmental studies. The Mid America Regional Council (MARC), the MPO for the Kansas City metropolitan area, uses the results of the CMP to prioritize large-scale corridor studies. Congestion management strategies selected from a CMP tool box become part of the NEPA alternatives analysis. The desire is to integrate congestion planning with the regional transportation plan, the transportation improvement program, corridor evaluations, and the major investment study planning process.

12. *The extent of the congestion challenge goes beyond one jurisdiction's boundaries and requires collaboration with many different organizations; in border areas, even with other nations.*

    Where capital investments in transportation facilities have long involved coordinated actions among different agencies, congestion traditionally has been viewed as a localized problem requiring localized traffic operations solutions. The extent and scope of congestion in many metropolitan areas, however, now requires multijurisdictional and multiagency strategies. Metroplan Orlando, the MPO for the greater Orlando region, believes that no single jurisdiction or organization can solve the region's transportation challenges. Given the regional impact on congestion resulting from the region's unique combination of commuters and visitors, collaboration of agencies and organizations within the region is critical to improving transportation system performance. This belief has resulted in the establishment of interagency partnerships that are the backbone of successful incident management and traffic signal timing and coordination initiatives.

    The active involvement of a broad range of agencies and stakeholders is one approach to achieving effective collaboration. Another is the establishment of entirely new organizations, commonly referred to as Transportation Management Agencies. The Transportation Operations Coordinating Committee, or TRANSCOM, covers the New York, New Jersey, and Connecticut region. AZTECH is a virtual organization for the Phoenix urban area in which the Arizona DOT and Maricopa County DOT are colead agencies. Operations planning by the Hampton Roads Planning District Commission is done in cooperation with the Virginia DOT's Hampton Roads Smart Traffic Center. The I-95 Corridor Coalition covers the entire eastern seaboard from Maine to Florida.

    The reliable movement of freight has become an important transportation policy and planning issue. Congestion management strategies increasingly are being looked at from a freight perspective, with particular attention being given to intermodal freight movements, such as those serving the Ports of Long Beach and Los Angeles. Strategies to reduce freight-related congestion commonly involve many different private and public entities, with freight moving across international borders also involving other nations.

Appendix A

Dallas-Fort Worth Metropolitan Area

A. Dallas-Fort Worth Metropolitan Area

A.1 Introduction and Background

The rapid growth of the Dallas-Fort Worth region has led to increasing transportation problems, including traffic congestion. During the past three decades, the region's population has grown by about 1 million every decade. Available financial resources to improve transportation have not been able to keep pace with this growth, resulting in increased traffic congestion and delay, as well as substandard air quality. The region's Congestion Management Process (CMP) seeks solutions to these growing traffic problems by targeting resources for operational management and travel demand reduction strategies.

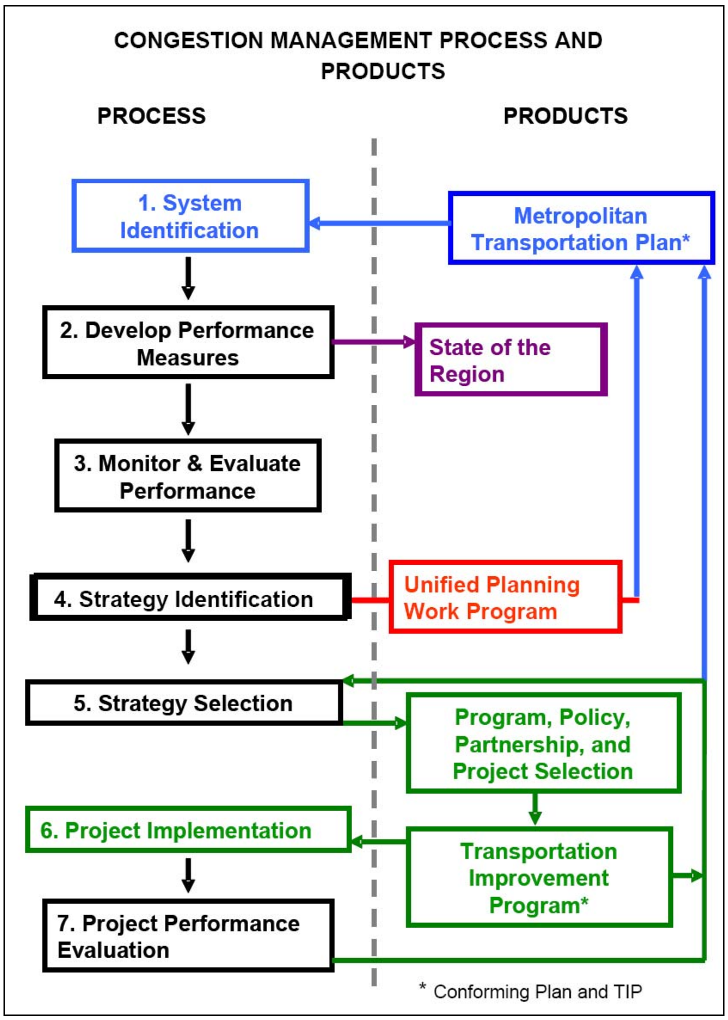
The North Central Texas Council of Governments (NCTCOG) helps communities in the 16-county region plan for common needs. NCTCOG's Transportation Department functions as the region's metropolitan planning organization (MPO). The MPO serves a nine-county area centered on Dallas-Fort Worth, with a population of 6 million and an area of nearly 5,000 square miles. The Regional Transportation Council (RTC) is the policy body for the MPO. The RTC consists of 40 members, predominantly local elected officials, overseeing the regional transportation planning process. NCTCOG's Transportation Department is responsible for support and staff assistance to the RTC and its technical committees, which fulfill the MPO's policy-making function.

A.2 Planning Process

The North Central Texas region's long-range transportation plan is known as the Metropolitan Transportation Plan (MTP) or "Mobility 2030" in its current version. This plan estimates that under a fiscally constrained revenue scenario, congestion in the region will continue to worsen. The plan identifies a range of systems management, demand management, and Intelligent Transportation Systems (ITS) strategies to manage congestion, in addition to capacity expansion projects.

NCTCOG's Congestion Management Process is a systematic process for managing traffic congestion and providing information on transportation system performance. It is fully integrated into the MPO's planning and programming processes and is elemental to development of the MTP, corridor studies, the Transportation Improvement Program (TIP), and the Unified Planning Work Program. Figure 1.1 illustrates NCTCOG's CMP and its relationship to other planning and programming activities. The first steps in the process are to identify system conditions and develop performance measures to identify congested areas and facilities. Congestion management strategies are then identified, selected, and implemented through the TIP, based largely on criteria for achieving the most cost-effective mobility and air quality benefits. Finally, NCTCOG tracks CMP project implementation through the TIP and evaluates impacts using a combination of observed data, modeling techniques, and regional performance studies.

Figure A.1 NCTCOG Regional Congestion Management Process and Products



Within the TIP selection process, strategies are chosen based on their effectiveness on a specific element of the metropolitan transportation system. For example, TDM and TSM strategies are focused primarily on regional arterial systems, whereas ITS strategies are focused largely on freight congestion. Congestion management strategies can typically be implemented in a relatively short timeframe compared to capacity projects.

A.3 Congestion Management Approaches

Congestion management strategies include the implementation of Transportation System Management, Travel Demand Management, and Intelligent Transportation Systems improvements.

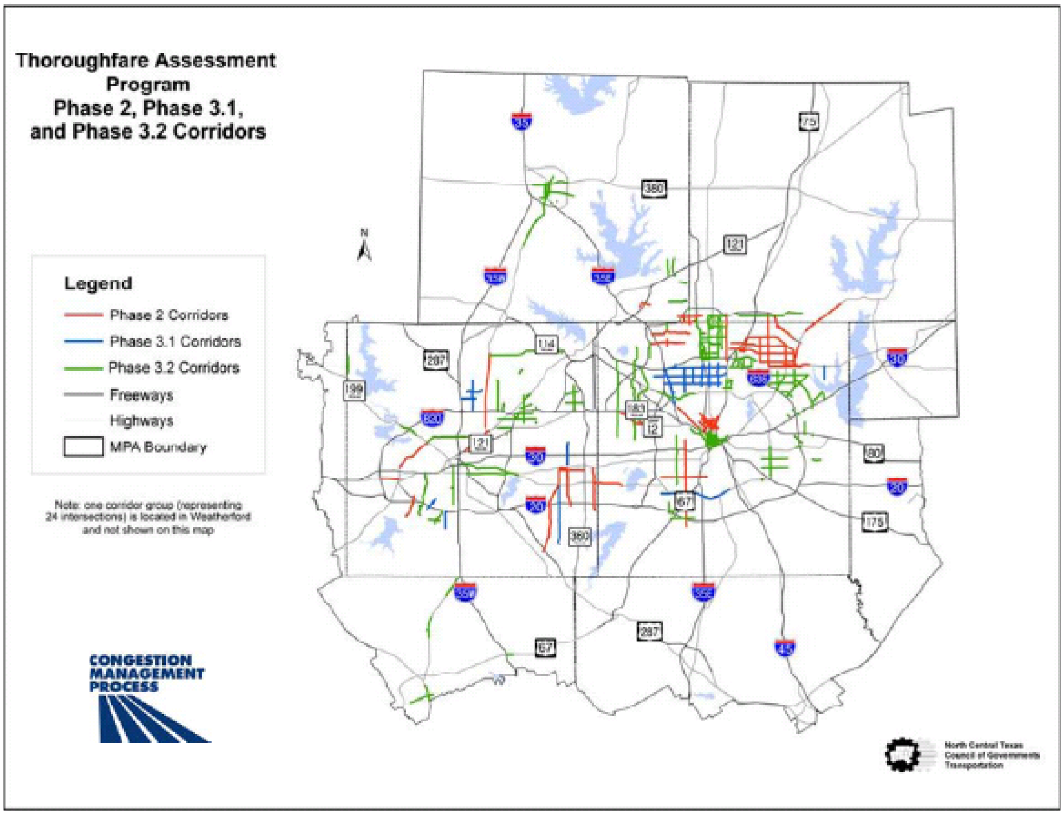
Transportation System Management

TSM strategies implemented by NCTCOG include traffic signalization and control; intersection and street improvements, such as street widening and installation of turn lanes; bottleneck improvements, such as the installation of signage and the reduction of merging; special event management; and access management.

Approximately 300 arterial intersection improvements are programmed in the current TIP. Intersection improvements include turn lanes, traffic islands, grade separations, and channelization. Additionally, a total of 1,000 traffic signal improvements are funded in the current the TIP. These projects include signal timing optimization, signal equipment upgrades, system interconnection, and the Traffic Signal Integration and Monitoring Project, also known as the Thoroughfare Assessment Program.

The Thoroughfare Assessment Program is a regionwide traffic-signal improvement program that includes a baseline analysis, recommendation and implementation of low-cost capital improvements, and an improved analysis. NCTCOG works on this endeavor with several city governments, including Dallas, Forth Worth, Irving, and Richardson, as well as Texas DOT regional offices in Fort Worth and Dallas. The goal of the program is to maximize the capacity of the existing system by improving traffic operations through signal retiming and implementation of low-cost operational improvements along selected corridors. As shown in Figure 1.2, this program has targeted selected corridors, including I-30 and I-820 in the Fort Worth area and I-20 in the Dallas area, as well as regional arterials.

Figure A.2 Thoroughfare Assessment Program Corridors



Source: http://www.nctcog.org/trans/cmp/SECTION3-Arterials.pdf.

The Thoroughfare Assessment Program includes data collection and system analysis. Performance measures include travel time, delay, number of stops, average speed, and emissions; each measure is both modeled and observed. Improvements in travel speeds before and after the implementation of congestion management strategies are measured. Pilot studies also have been conducted of truck lane restrictions using observed ITS data on speeds and volumes by lane. As a result of implementing new optimized signal timing and recommended low-cost operational improvements along corridors, the following benefits have been quantified along these corridors:

- A 16 percent to 31 percent decrease in travel time;
- A 39 percent to 67 percent decrease in delay;
- A 30 percent to 58 percent decrease in the number of stops;
- A 20 percent to 51 percent increase in the average speed;
- A 9 percent to 13 percent reduction in volatile organic compound emissions; and
- A 3 percent to 7 percent reduction in nitrogen oxide.

Travel Demand Management and Transit

TDM strategies include improving transportation options, such as alternative work schedules, vanpooling/carpooling, park-and-ride, and bicycle pedestrian improvements, and other incentives for alternative modes, such as guaranteed ride home programs. NCTCOG also considers sustainable development, including transit-oriented development and land use planning, a TDM strategy.

Transit operations comprise a major component of the region's congestion management strategy. Currently, Dallas Area Rapid Transit (DART), Denton County Transportation Authority (DCTA), and the Fort Worth Transportation Authority (The T) provide transit service throughout the Dallas-Fort Worth Metropolitan Area. Together, they carry more than 100 million passengers annually on bus, light rail, commuter rail, and HOV lanes. DART currently operates 45 miles of light rail transit; the Trinity Railway Express, a cooperative commuter rail service provided by DART and The T, includes approximately 35 miles of track linking downtown Fort Worth, downtown Dallas, and the Dallas/Fort Worth International Airport. Transit ridership increased for all agencies between 4.6 and 13 percent in 2006. In both 2007 and 2008, the Federal Transit Administration gave the T an Annual Award for Success in Enhancing Ridership, for developing programs that enhanced overall ridership by about 10 percent. A campaign was developed in 2005 to target "choice" commuters with a strong cost-saving message to use public transportation as an alternative to their personal vehicle due to high gasoline prices. An advertising campaign targeting schools and colleges offered free annual ridership passes to students, faculty, and staff. Ridership in The T's service area currently is increasing at a rate of about 2 to 4 percent per month.

Improvements to transit have been made in recent years by expanding service and improving facilities. DART is increasing service and expanding lines, DCTA has expanded its Commuter Express, the Trinity Railway Express has received track upgrades, new and improved facilities, and the T has collaborated with cities to provide express bus park-and-ride services for commuters. The region currently is in the process of examining the expansion of passenger rail.

Another NCTCOG TDM strategy to reduce congestion in the region is a web-based educational program called "tryparkingit.com." The program enables the public to record information about their alternative commutes. Since the program began in October 2006, the web site has recorded over 753,000 miles of alternative commute modes. The program now offers gift-card incentives to residents who share a ride to the office, work from home, or choose another alternative to driving alone.

Intelligent Transportation Systems

The North Central Texas region is using the National ITS architecture as a model for ITS deployment and to build consensus for multi-agency systems integration. Traffic monitoring and incident detection and response systems are operating on portions of the region's freeway system through a satellite traffic management center jointly operated by Texas DOT and DART. Funds have been committed for a permanent traffic management center and the installation of a staged communication infrastructure has begun.

The region has implemented several key ITS applications to help reduce congestion. For example, traffic management centers, managed by TxDOT, provide information hubs to monitor system congestion and detect incidents through receipt and processing of data from several ITS devices. ITS components of the traffic management centers include closed-circuit television, ramp meters, and vehicle detectors. Closed-circuit television cameras monitor traffic conditions, special events, and emergency situations on freeways, frontage roads, and arterials. In addition, ramp metering systems use traffic signals and loop detectors on freeway entrance ramps to space vehicles entering the freeway lanes, allowing a smooth merge into traffic that reduces delay-causing incidents. Vehicle detectors collect valuable information regarding traffic conditions, including volume, speed, and density. In the Dallas-Fort Worth region, two types of technologies are used: loop detectors and Automatic Vehicle Identification (AVI) technologies. Loop detectors, placed in the pavement of roadways, are the most commonly used technology. The AVI system operates through the use of AVI antennas and readers that monitor the passage of vehicles equipped with toll transponder tags.

Strategy identification within the Congestion Management Process includes several ITS strategies, including traffic management, public transportation, and traveler information. Current ITS projects that help manage congestion include network surveillance, multimodal coordination, and broadcast traveler information. Network surveillance, a type of traffic management strategy, uses traffic sensors to transmit data collected along roadways back to Traffic Management Centers. An example of a public transportation ITS project is multimodal coordination, which establishes two-way communications between multiple transit and traffic agencies to improve service coordination. Automated Traveler Information System projects include broadcast traveler information, which collects and distributes general traffic conditions and advisories for travelers.

According to the Texas Transportation Institute, estimated benefits of ITS strategies include a reduction of over 68,000 person hours per day in recurring traffic congestion and over 123,000 person hours per day resulting from reductions in the number and duration of traffic incidents. Several ITS strategies are implemented and evaluated in the Thoroughfare Assessment Program and transportation capacity increases of up to 30 percent have been realized. ITS data and systems also support development and maintenance of the regional travel demand model as well as monitoring of system performance.

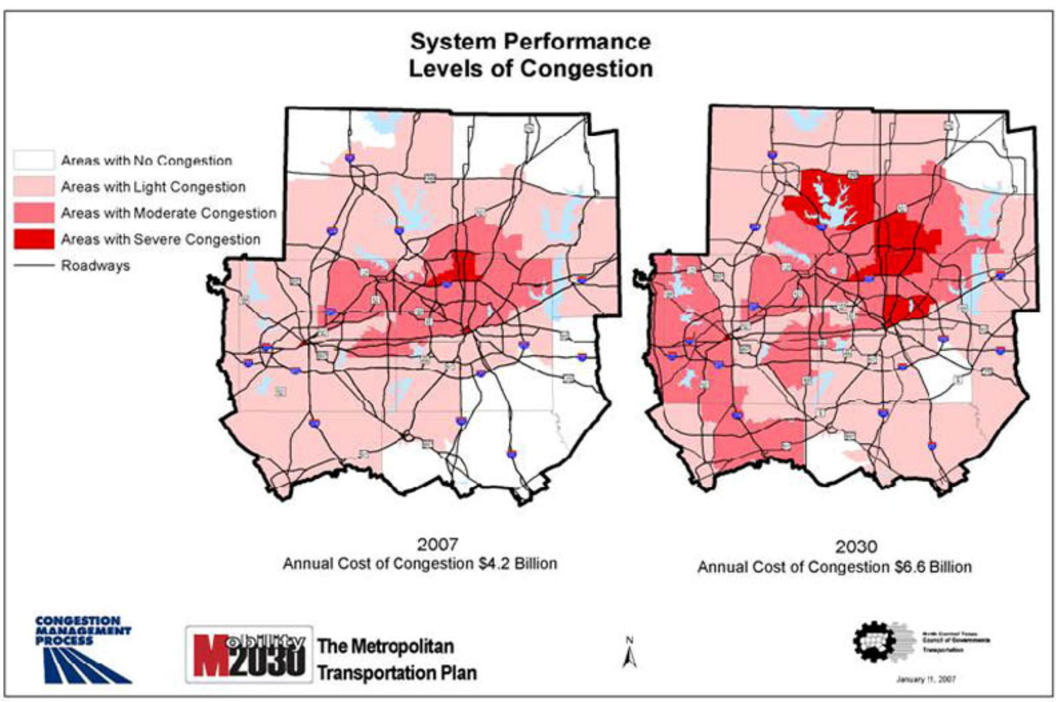
A.4 Performance Measurement

An important aspect of the CMP is to develop and use performance measures that can accurately monitor and evaluate the overall performance of the system.

"Transportation: State of the Region," an annual NCTCOG report providing a summary of the transportation system's performance, reports on impacts of the CMP. CMP activities also include evaluation of the effectiveness of individual projects in mitigating congestion.

The MPO has gathered stakeholder and public input to assist in defining congestion-related performance measures. Performance data collected on the regional freeway and arterial system through monitoring includes VMT as well as vehicle counts. In addition, the regional travel demand model is used to develop travel-time contours and level of service measures. The Dallas-Fort Worth Regional Travel Model is used to project future travel conditions and evaluate the performance of freeway, rail, HOV lanes, and regional arterial systems for inclusion in the MTP. Indicators of congestion are presented to the public in easy-to-understand maps rather than through technical performance measures such as level of service (LOS). Figure 1.3 provides an example of a "blob" map. In this example, NCTCOG used forecasts to determine future congestion under a constrained funding scenario and compared it with current levels of congestion. In the 2007 "State of the Region" report, MTP congestion maps indicated that congestion is increasing at lower rates from the previous Plan's predictions, an indicator that congestion strategies may be working.

Figure A.3 Forecasts of Congestion Levels in Dallas-Fort Worth Metro Area
2007 and 2030



Much like a weather map indicating the amount of rainfall through coded colors, the blob maps indicate areas of moderate and severe congestion. The maps are created using the percentage of congested (LOS D, E, or F) roadways and modeled with observed data. When segments of roadways speeds are between 30-50 mph, the area is shaded with a "moderate or intermittent congestion" label; areas are labeled with "severe congestion" when speeds fall below 30 mph. Freeway traffic quality ratings, or summaries of density-based LOS, also are used to determine congestion levels. Maps are created for current years with observed data, and for future years with modeled data for various transportation plan scenarios.

In addition to vehicular volume data collected by the Texas DOT using pneumatic tubes, NCTCOG conducts aerial photography that includes a time-slice of one-hour segments on freeways during the morning and evening peak-travel periods. Vehicle density information from these photographs is translated into level of service. The findings are used to highlight the locations of peak-period traffic bottlenecks, identify heavy truck traffic corridors, and assess the impacts of congestion caused by incidents and accidents. The MPO uses the various data collected to develop a set of multimodal congestion-related performance measures as shown in Table 1.1. Nonrecurring congestion is an important focus; NCTCOG and TxDOT use video and speed information from ITS equipment to help measure the frequency and impacts of nonrecurring congestion. The MPO uses this data to produce maps for plans and public consumption depicting the percentage of time that commuters on controlled access facilities encounter with speeds less than 35 mph.

Table A.1 NCTCOG Primary Congestion Management Performance Measures

Facility Type	Performance Measures	Observed or Forecast Data	Source
Controlled-Access Facilities	Levels of Service	Forecast/Observed	Regional Travel, Model/Aerial Photos
(General purpose lanes, HOV lanes, managed lanes)	Reliability	Observed	Speed Sensors, ITS Data Archive Project
	Travel Time	Modeled/Observed	Speed Sensors, ITS Archiving Data, NTTA, Addison Tunnel
	VMT	Modeled	Regional Travel Model
	Vehicle Classification	Modeled/Observed	Regional Travel Model, ITS Data Archive, TxDOT Saturation Counts
Regional Arterial System	Volumes (7-day and 24-hour vehicle counts)	Observed	Thoroughfare Assessment Program, TxDOT, Traffic Count Web Site

Facility Type	Performance Measures	Observed or Forecast Data	Source
Intermodal/Freight System	Freight Rail Forecast	Forecast	DFW Regional Travel Model
	Truck Traffic Forecast (used to identify future bottleneck locations)	Forecast	DFW Regional Travel Model
	Vehicle Classification Counts	Observed	TxDOT, Thoroughfare Assessment Program
Passenger Rail Transportation/Transit	DART Light Rail Train Ridership	Observed	DART Data Collection
	TRE Ridership from West to East	Observed	TRE Data Collection
	TRE Average Weekday Ridership by Station	Observed	TRE Data Collection
	Transit Forecasts	Modeled	DFW Regional Travel Model

Source: Regional Mobility Initiatives Volume XII, No. 1 April 2008 and DFW CMP Documents 2007.

NCTCOG also uses project-specific performance measures to help understand and pinpoint effective strategies for congestion management. NCTCOG conducts project performance evaluation studies with the goal of having a continuous program to evaluate the benefits of operational and demand reduction strategies. Examples include before-and-after studies of travel speeds and delay along major thoroughfares, as described previously.

Performance measures also have been developed for the passenger rail and intermodal/freight rail systems. Passenger rail measures include on-time performance, route transit flow information, transit passenger miles, and park-and-ride lot usage. Freight measures primarily focus on forecast traffic volumes, as a way of helping to identify potential future bottlenecks.

According to the April 2007 CMP Technical Briefing Report, effective implementation of multimodal options, trip reduction programs, system management projects, and other travel policies will help reduce congestion. Yet the region's population will likely continue to grow faster than the capacity of the transportation system, due to implementation issues and financial constraints. Under the constrained budget scenario in the MTP, travel time due to congestion is expected to increase by 36 percent with an annual congestion cost of $6.6 billion. New innovative funding sources are being examined to help overcome this gap and to improve congestion problems.

A.5 PARTNERSHIPS AND PUBLIC OUTREACH

Planning and implementing an integrated transportation system for the Dallas-Fort Worth region requires the close coordination of many transportation partners. Freeways, tollways, high-occupancy vehicle (HOV)/managed lanes, transit, and airports combine to move people and freight within the region and the success of the system depends on the agencies involved working together. The Regional Transportation Council is responsible for developing a long-range transportation plan, allocating Federal funding to projects and programs, and setting regional transportation policy. This planning is carried out in cooperation with the agencies that implement transportation throughout the area.

The region is divided between two Texas Department of Transportation (TxDOT) districts. The Dallas and Fort Worth TxDOT offices are responsible for the design, construction, operation, and maintenance of the Federal and state highway system. TxDOT also has authority to enter into public-private partnerships, known as Comprehensive Development Agreements.

The North Texas Tollway Authority (NTTA) serves as the region's toll road provider and operates four facilities in the region. Toll roads are an important feature of the transportation system, raising revenue while easing regional traffic congestion by providing additional capacity. TxDOT and the MPO have partnerships with the NTTA, which manages the engineering, construction, maintenance, toll collection, and repair of toll roads. NTTA receives investment-grade traffic and revenue studies from the TxDOT, the MPO, and the RTC. Final funding agreements for NTTA's first fully electronic toll collection facility, the Southwest Parkway, have been made and it is expected to open in 2010.

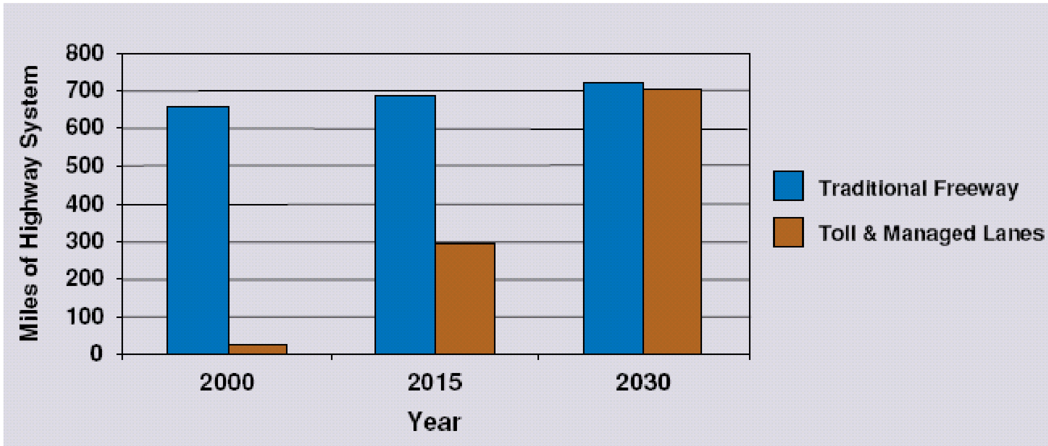
Because congestion is an important issue with the public, the region's residents are typically supportive of many congestion management projects. NCTCOG tries to present a consistent message with the public through congestion blob maps and other web-based communication tools. Low-level aerial photography is used to educate the public about how congestion is getting worse and what the strategies and options are for dealing with the growing congestion.

A.6 Funding

The North Central Texas region frequently funds transportation projects through partnerships that help leverage needed revenue. The main sources of money for congestion management projects are the Federal Congestion Mitigation and Air Quality Improvement Program (CMAQ), the Surface Transportation Program (STP), and local toll revenue funds. Also, DART has a congestion management fund that provides money to local agencies within its service area to undertake demand management projects. Some cities even use this money as local match for NCTCOG signal retiming projects.

Texas and the Dallas-Fort Worth metro area have limited resources for highway maintenance and construction; therefore, user fees are needed to help close the funding gap. Most new planned or under development highway facilities are tollways and/or managed lane roads that will produce their own revenue for maintenance, reconstruction, and expansion. Figure 1.4 illustrates the growth in revenue-producing expansion of the highway system.

Figure A.4 Growth of Revenue-Producing Highway System in Dallas-Fort Worth Metro Region
2000-2030



There are several agreements between the TxDOT and political jurisdictions within the Dallas-Fort Worth region for funding and revenue. Tolling Service Agreements (TSA), such as the Comprehensive Development Agreement Memorandum of Understanding (CDA MOU) enacted between TxDOT and NTTA in 2006, identify mandatory and optional services for NTTA to provide CDA projects. The CDA MOU calls for project-specific Tolling Service Agreements for the first five years of revenue service and will include services such as account management, transaction, and payment processing, and video billing services for all CDAs in North Central Texas under the terms of the TSA. Other agreements are the Regional Revenue Sharing Fund for Surplus Toll Revenues and CDA Concession Payments MOU, as signed by TxDOT and the Regional Transportation Council. They ensure that toll revenues collected within the region stay within the region. TxDOT accounts for the funds and interest earned separately from other money. The RTC, working with local governments, TxDOT, and other transportation partners, selects the projects funded from the toll and CDA revenues. The first Comprehensive Development Agreement procurement for the region took place in February 2007 for State Highway 121. It is anticipated that Cintra Concesiones de Infraestructuras de Transporte SA will provide $2.8 billion in concession payments to the region and also will pay to construct and maintain the corridor. Although the region has taken an aggressive innovative funding approach, Mobility 2030 estimates that more funds will be needed to mitigate congestion.

A.7 Concluding Observations

The North Central Texas region, centered on Dallas and Fort Worth, has a comprehensive congestion management process with extensive implementation and monitoring of strategies to combat congestion. The process is founded partially on public support facilitated over the years through numerous outreach efforts to engage the public. Because some parts of the region face more congestion than others, however, the public outreach and education process can be challenging for the MPO and TxDOT because it is sometimes difficult to convincingly articulate why funds are allocated across the region as they are. To garner broader public support for CMP strategies and funding allocations, the MPO and TxDOT need to provide a compelling and consistent public message on the benefits of these efforts.

Many of the operational congestion management strategies require significant stakeholder and agency buy-in and cooperation; this requires a lot of time and effort on the part of NCTCOG and TxDOT. One aspect of congestion management under consideration is how to implement low-cost, "quick-start" strategies. While the MPO is hoping to use local and toll revenue dollars to help expedite these types of projects, they will still need to be programmed through the normal TIP process. The region also recognizes the need to focus efforts on finding more innovative funding sources to successfully mitigate congestion in the face of rapid population and economic growth.

Appendix B

Minneapolis-St. Paul Metropolitan Area

B. Minneapolis-St. Paul Metropolitan Area

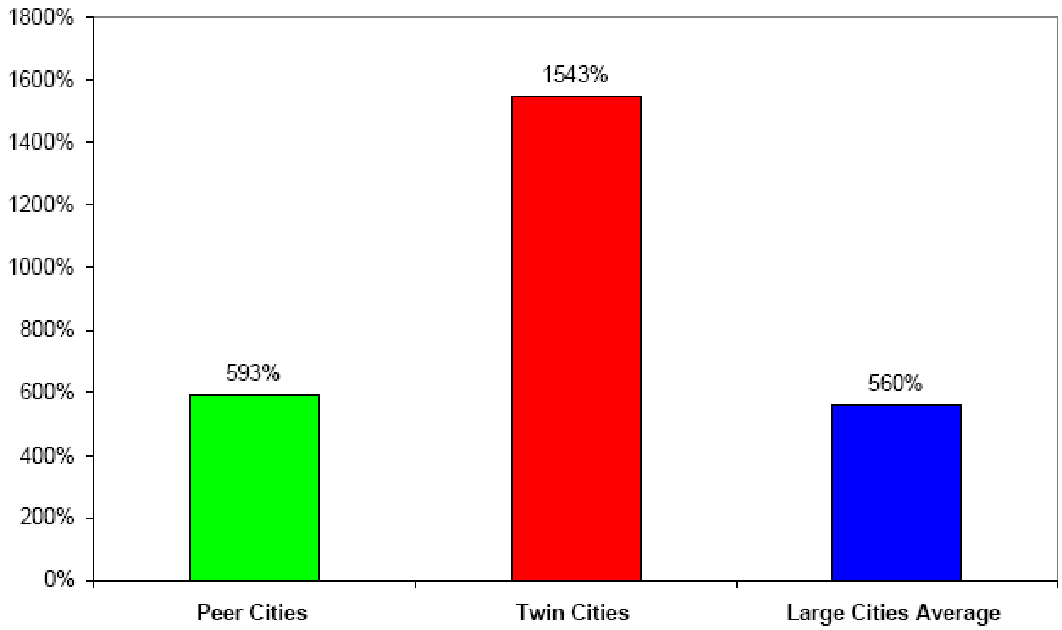
B.1 Introduction and Background

Since 1970, the population of the Minneapolis-St. Paul, Minnesota ("Twin Cities") metropolitan area has grown by 767,000, or more than 40 percent. During this same period, the region has experienced a dramatic increase in automobile ownership, increased decentralization of jobs, and suburbanization. Although these factors have precipitated growth in congestion, the Minnesota Department of Transportation (Mn/DOT) and the Metropolitan Council (Met Council, the region's metropolitan planning organization) have together been national leaders in congestion management strategies. Congestion management in the Twin Cities region focuses on providing safe and effective management and operation of new and existing transportation facilities using demand reduction and operational management strategies.

Largely due to increased population, congestion in the region has worsened. In 1990, 30 percent of the Twin Cities region freeway lanes were congested during peak periods; by 2000, the figure had grown to 60 percent. The number of congested highway lane-miles in the seven-county metro area almost doubled from 1997 to 2007. The Texas Transportation Institute's 2007 Urban Mobility Report found that overall, Twin Cities metro area commuters wasted an average of 43 hours stuck in traffic in 2005, resulting in an average cost of $790 per commuter. In the Met Council's 2004 survey of Twin Cities area residents, traffic congestion ranked as the top concern, outpacing crime, education, and housing. Figure 2.1 compares change in average delay in the Twin Cities metropolitan region to other peer and large city areas across the country between 1983 and 2003.

The Met Council and Mn/DOT missions include undertaking continuing efforts to ease traffic congestion in the Twin Cities region. The Minnesota state legislature created the Met Council in 1967 to ensure coordinated, economical development in the seven-county Twin Cities metropolitan area. In addition to planning functions, the Council operates the principal regional transit system (Metro Transit). Mn/DOT addresses traffic congestion in the Twin Cities region by managing traffic flow on freeways, improving bottlenecks on the freeway and state trunk highway system, and supporting regional transit projects.

Figure B.1 Change in Delay
1983-2003



Source: TTI Urban Mobility Report, as reported in Metropolitan Council, 2005 Transportation Audit.

B.2 PLANNING PROCESS

The Met Council, working with Mn/DOT, the Transportation Advisory Board (the MPO policy board), and its Technical Advisory Committee, has developed a Congestion Management Process (CMP) that provides the region's philosophy, policy direction, and tools for managing highways. The Met Council – Mn/DOT CMP has long been a criteria-driven process and predates the Congestion Management Systems requirement of the Intermodal Surface Transportation Efficiency Act (ISTEA) of 1991.

The Congestion Management Process is linked directly to the most recent update of the Met Council's Transportation Policy Plan (TPP). The TPP, under the umbrella of the Council's adopted 2030 Regional Development Framework, contains policies and strategies designed to slow the growth in congestion and to improve mobility. TPP recommendations include investing in multimodal transport, expanding transit services, and encouraging local communities to interconnect arterials and local streets, pathways, and bikeways.

Explicit criteria in the Transportation Improvement Program (TIP) project selection process give local governments an incentive to propose CMP-supportive projects. After the passage of ISTEA, the Met Council and its regional partners developed a substantially new competitive process to select projects funded under various Federal funding categories, including the Congestion Mitigation and Air Quality Improvement Program (CMAQ). This process prioritizes about

55 percent of the Federal transportation funds that are available to the region. The regional partners designed the process to ensure that Federal Title I funds would help the region implement its plans and high-priority projects and programs, consistent with the goals and policies in the Regional Development Framework and Transportation Plan. The Met Council uses a variety of criteria to determine project priority rankings, including, among others, reduction of congestion on principal or minor arterials, integration of modes, and increase in hourly person throughput. All projects in the TIP are reviewed by the Transportation Advisory Board and the Met Council for consistency with the TPP and the Air Quality Control Plan.

Met Council staff believe that the cross-disciplinary/multijurisdictional Transportation Advisory Board has maintained an equitable approach and has been strong about not always "bowing down" to challenging political situations, thereby ensuring that funds are directed at effectively achieving congestion management and other regional objectives.

B.3 Congestion Management Approaches

The Twin Cities region has a long history of developing innovative traffic management and congestion management initiatives. Well-established initiatives include ramp metering on the entire metropolitan freeway system, as well as system enhancements that support transit and ridesharing, including ramp meter bypasses for buses and carpoolers, high-occupancy vehicle (HOV) lanes, bus use of shoulders, and a developing fixed-guideway transit network. Recent initiatives include an Urban Partnership Agreement with the U.S. DOT to fund innovative congestion management strategies, as well as Integrated Corridor Management to improve traffic and transit operations along arterial corridors.

Ramp Metering

The Twin Cities area has one of the nation's most extensive and sophisticated expressway ramp metering systems, whose origins date back to the late 1960s. Mn/DOT uses around 430 ramp meters to manage about 210 miles of freeways in the Twin Cities metropolitan area so that they move more smoothly and maintain high average speeds throughout the system. Over a 14-year implementation period, peak-period freeway speeds remained 16 percent higher (from 37 to 43 mph) even while volumes increased 25 percent. Mn/DOT has continued to make enhancements to improve the sophistication of the metering system.

In 2000, under a legislative requirement, Mn/DOT conducted a study of the effectiveness of the ramp meters in the region involving the shutdown of the ramp-meter system. Through its study of the shutdown consequences, Mn/DOT confirmed many of the suspected benefits of ramp-metering, including:

- During peak-traffic conditions, freeway mainline throughput declined by an average of 14 percent in the "without meters" condition.
- Without meters, the decline in travel speeds on freeway facilities more than offsets the elimination of ramp delays, resulting in annual systemwide savings of 25,121 hours of travel time with meters.
- The ramp metering system produces an annual reduction of 2.6 million hours of unexpected delay.
- Ramp metering results in annual savings of 1,041 crashes or approximately 4 crashes per day.
- Ramp metering results in net annual savings of 1,160 tons of emissions.
- Ramp metering results in annual savings of approximately $40 million to the Twin Cities traveling public. The benefits of ramp metering outweigh the costs by a significant margin and result in a net benefit of $32 to $37 million per year. The benefit/cost ratio indicates that benefits are approximately five times greater than the cost of entire congestion management system and over 15 times greater than the cost of the ramp metering system alone.[1]

Based on these study results as well as growing congestion and increasing demand for higher-quality transit services, the ramp metering system has been largely reactivated. One relatively unique aspect of the metering system is its use on key bus routes, providing transit with advantages to make it more time-competitive through the use of ramp meter bypass lanes.

Transit

Metro Transit – an operating branch of the Metropolitan Council – provides more than 90 percent of the region's transit services. These services include buses, trains (one light rail line operating and other light rail and commuter rail lines in the planning stages), car and vanpools, park-and-ride lots with express bus service, transit hubs, and HOV lanes. The rideshare program also includes bicycle programs. In addition, 10 small urban systems and eight rural systems operate local transit for their communities. Metro Transit also provides specialized, demand-response services such as the Dakota Area Resources and Transportation for seniors within the region.

Mn/DOT and the Met Council have implemented a number of system operations strategies that provide travel-time advantages to buses under congested conditions. The region's extensive metering system provides the opportunity for bypass ramps. The first expressway bus bypass ramps were built in the 1970s as a Federal demonstration project. Eighty-eight HOV ramp bypasses controlled by meters on area freeway entrances now provide carpoolers and buses with

[1] *2005 Twin Cities Transportation System Performance Audit*, page 51.

preferential and quick access to the highway. The bypasses are located on the most heavily traveled segments of the regional highway system. Furthermore, working in cooperation with the Met Council, Mn/DOT began construction of extensive bus shoulder lanes 1992, which has continued to this time. As of late 2004, there were 223 miles of bus shoulder lanes in the metro area. Figure 2.2 displays the current and planned bus-only shoulder lane network for the region. In addition, the region has two HOV lane routes approaching downtown Minneapolis, one on I-394 from the west, and one on I-35W from the south.

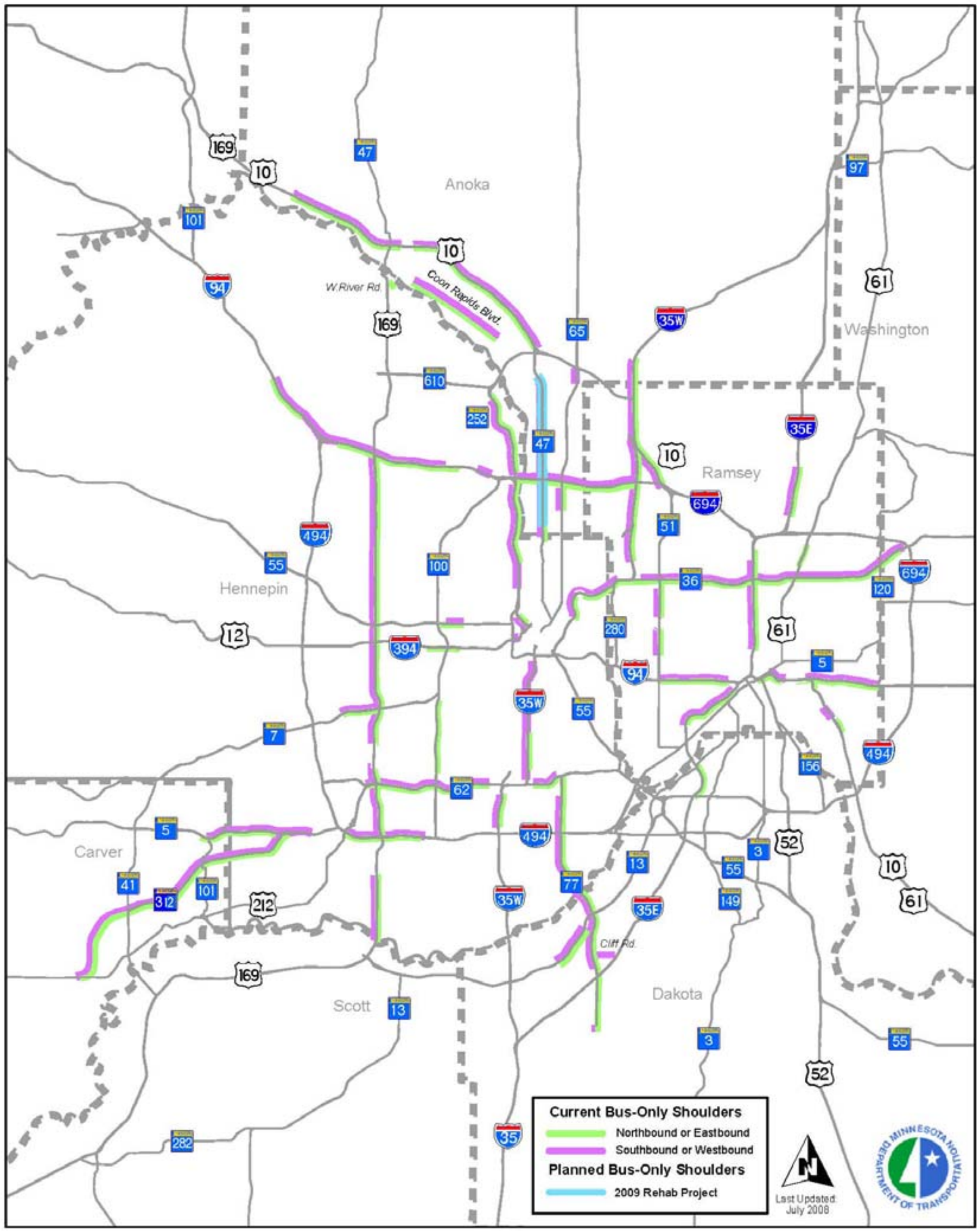
Working jointly, Metro Transit, the Met Council, Mn/DOT, and several cities and counties have developed other transit preferences on the roadway system, including signal priority points for buses and direct highway access for buses from park-and-ride lots. In addition, there are bus lanes on various central city streets as well as the University of Minnesota Transitway. New Metro Transit bus and rail control centers have recently been completed and are equipped with the latest Intelligent Transportation Systems (ITS) technologies. One of the newest technologies being developed to improve transit service delivery is the "Go-To Card," which will increase the efficiency of fare collection by reducing the average fare collection time per passenger.

The region plans for the bus system to remain the foundation of future transit services, focusing the highest level of service on arterial corridors as well as selected high-traffic urban and suburban streets. To facilitate future bus lane development and where funding and design constraints allow, Mn/DOT builds 12-foot shoulders on new highway projects so they can be converted to bus lanes in the future. However, the region also is working toward developing a network of dedicated transit corridors, including light rail and commuter rail as well as busways. The first rail line, the Hiawatha Line, opened in 2004 and ridership already has exceeded forecast levels for 2020.

The Met Council recognizes that service levels and types need to continue expanding to meet growing demand and address congestion. As shown in Figure 2.3, transit ridership has generally increased since 1996 (with a minor downturn in 2002-2004 that is likely related to the economic slowdown as well as a transit strike during 2004). The Met Council's Transportation Policy Plan contains a transit plan that seeks to double ridership from present levels by 2030. These transit goals would be accomplished by increasing bus services, converting highway shoulders into bus shoulders, providing transit fare incentives, and developing a network of dedicated "transitways," with mode choices based on a careful benefit/cost analysis. Figure 2.4 depicts the Met Council's transitway plan through 2030.

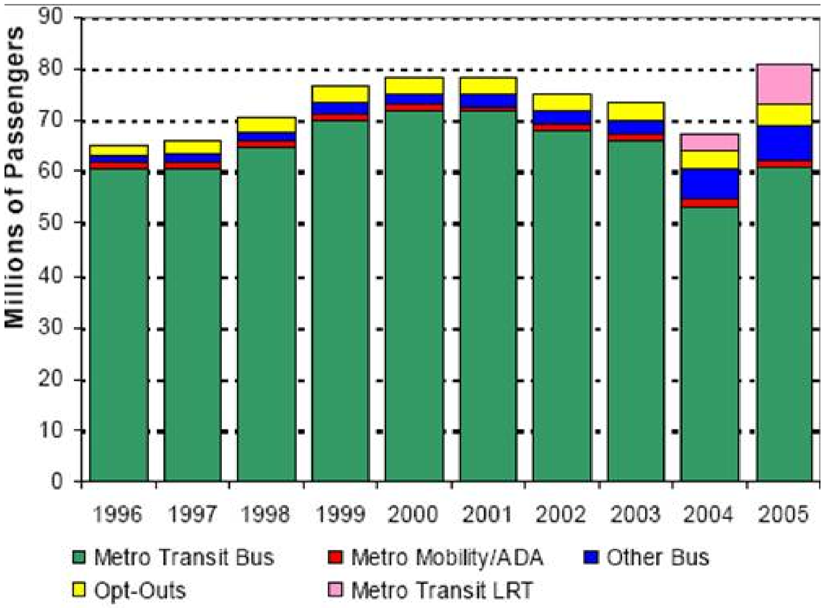
The Twin Cities' transit services are delivered through several programs. There are regular route services throughout the five-county transit taxing district, which imposes a 0.25 percent sales tax to fund transit operations. Regional transit service providers cover "opt out" areas outside of the Metro Transit service area. Metro Transit also contracts for about 5 percent of the regular route service through private and nonprofit providers.

Figure B.2 Current and Planned Bus-Only Shoulder Lanes in the Twin Cities Metropolitan Region



Source: Mn/DOT.

Figure B.3 Twin Cities Region Transit Ridership (All Providers)
1996-2005



Source: Metropolitan Council 2005 Twin Cities Transportation System Audit.

Figure B.4 Planned Twin Cities Region 2030 Transitway System

Urban Partnership Agreement

The Met Council and Mn/DOT were recently awarded an Urban Partnership Agreement (UPA) by the U.S. DOT, which will fund a new set of innovative congestion management activities in the region. In 2007, the DOT awarded five UPAs that are funding efforts to aggressively use four complementary and synergistic strategies to relieve urban congestion: tolling, transit, telecommuting, and technology. The Minneapolis-St. Paul region's UPA initiative includes tolling/congestion pricing, including dynamically priced shoulder lanes; additional ITS deployment related to TDM, such as parking and transit information; bus rapid transit (BRT) expansion; and public-private telecommuting initiatives. UPA activities will focus on improving traffic flow on I-35W between downtown Minneapolis and the southern suburbs, the most heavily congested corridor in the region. Metro Transit will design and build three new park-and-ride lots along I-35W, adding 1,400 new parking spaces. Plans also are being developed to convert HOV lanes to high-occupancy toll (HOT) lanes. A major underpinning of the UPA approach in the Twin Cities is developing extensive real-time information on travel and transit conditions with widespread and easy accessibility for travelers.

Integrated Corridor Management

The Met Council and Mn/DOT also are pursuing integrated corridor management (ICM) options under the UPA and a separate U.S. DOT ICM Pilot Program. As part of the UPA, an Arterial Management System will be deployed on Trunk Highway (TH) 13. The system will include 17 cameras, six changeable message signs, and fiber optic signal interconnections. Additional deployments of Arterial Management Systems are planned for several additional highways in the Twin Cities region. In addition, Mn/DOT is pursuing signal optimization in at least three corridors: TH 13 at 14 intersections; I-394 at 25 ramp intersections; and TH 212 at 30 intersections. The lowest calculated benefit/cost ratio for any of these optimization efforts is 21:1. [2]

B.4 Performance Measurement

The Met Council performs a regional "Transportation Audit" every four years per legislative requirement for Minnesota. It includes a review of the transportation system performance since the last performance audit, a comparison of the performance to peer urban areas, and a comparison of service to existing standards or benchmarks. Among the performance measures used to gauge congestion in the region are miles of congested freeway. Figure 2.5 illustrates the change from 1995 to 2004.

Mn/DOT defines congestion as traffic flowing less than or equal to 45 miles per hour on a freeway (the Met Council uses the same definition). Mn/DOT selected this speed since it is the speed where "shock waves"[3] can occur and pose higher risks for crashes. Since the early 1990s, Mn/DOT has produced an annual Metropolitan Freeway System Congestion Report that documents segments of the Twin Cities region freeway system that experience recurring congestion. The report is intended to identify under-capacity locations, facilitate project planning, help allocate Mn/DOT resources (including ITS equipment and incident management planning), help plan construction zones, and provide department performance measures.

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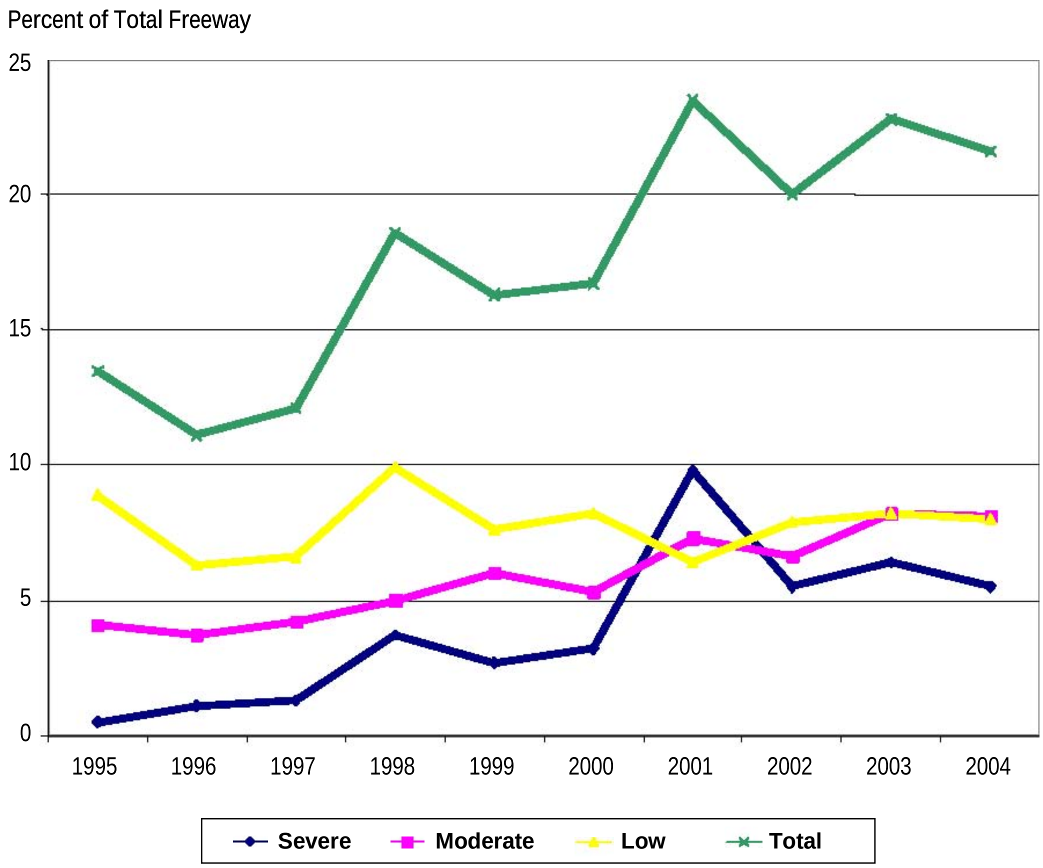
[2] *Active Traffic Management at Mn/DOT* (PowerPoint presentation), Kenneth R. Buckeye, AICP, Value Pricing Program Manager, Minnesota Department of Transportation, 2008.

[3] A "shock wave" is a phenomenon where the majority of vehicles brake in a traffic stream. See Mn/DOT, *Metropolitan Freeway System 2007 Congestion Report* (March 2008), for more information.

Figure B.5 Percent of Miles in Congested Conditions
1995-2004



Source: Metropolitan Council 2005 Transportation Audit.

B.5 PARTNERSHIPS

In the early 1990s, the Met Council and Mn/DOT initiated the "Team Transit" concept to help facilitate improved transit operations and greater transit usage. The primary players were Mn/DOT and Metro Transit; other agencies involved in creating Team Transit included the Center for Transportation Studies at the University of Minnesota, the Minnesota State Patrol, and representatives from Minneapolis, St. Paul, and other municipalities served by transit. The primary goal of Team Transit was to focus on maximizing the number of people moving throughout the Twin Cities, rather than the number of vehicles. This effort has facilitated Metro Transit's ability to "cut through red tape" to address mobility needs for transit providers. Bus-only shoulders were the first, and remain the primary, focus of the team and have helped alleviate congestion by increasing transit usage. Metro Transit used an annual commuter challenge in the 1990s to publicize bus shoulder lane benefits.

In the 1990s, Mn/DOT combined its East and West (Twin Cities) Metro Area offices into one facility to better integrate resources and people. Mn/DOT also developed a Metropolitan Operations Plan to better match its sequencing of project development efforts with the Met Council's regional Long-Range Transportation Plan.

B.6 FUNDING

Statewide, Mn/DOT derives highway funding primarily from two sources: Federal highway grants and state funds, with the state funds coming mainly from a state gasoline tax, motor vehicle license fees, and motor vehicle sales tax. There has been little road capacity expansion money since 1988, yet the Met Council, in partnership with Mn/DOT, has created congestion management strategies and funded them through a variety of means. Five of the seven counties within the region impose a quarter-cent sales tax, primarily funding "transitways," or bus lanes. Revenues from increases to the state gas tax must constitutionally be spent on roads, which assist with congestion alleviation. The state motor vehicle sales tax provides funds for highways and transit. The Met Council also can sell bonds, but needs legislative approval of the amount.

The Met Council historically has used the CMAQ program to fund major CMP initiatives in the region and traffic operations in the cities. Although not a nonattainment area, the Twin Cities is a maintenance area for carbon monoxide (CO), meaning the U.S. Environmental Protection Agency previously cited the area for not meeting CO standards but now legally recognizes the area as meeting (attaining) these standards. The designation means that CMAQ funds are available to the region for projects that contribute to meeting or maintaining air quality standards. The Met Council also has recently created different funding categories for transportation system management and operations and travel demand management.

In odd numbered years, the Council and its Transportation Advisory Board select projects for CMAQ funding. The two-year selection process involves solicitation of projects from Mn/DOT, cities, counties, and transit providers, evaluation and ranking of these projects by the TAB and Technical Advisory Committee, and selection of a list of approved projects. Applicants who document a benefit to congested roadways from a proposed CMAQ project will receive extra points in the project prioritization process. Approximately one-quarter of possible points in the project scoring process accrue from direct congestion mitigation benefits, including addressing congested roadways and reductions in single-occupancy vehicle trips and/or VMT.

The Met Council also recently has created different TIP funding categories for transportation system management and operations and travel demand management. In 2007, the Met Council created a CMAQ category called "Transportation System Management," (TSM) in addition to a category for transit capital and operating expansion and a set-aside for travel demand management. This TSM category is specifically targeted to corridor management and efficiency projects. In 2007, the Met Council allocated TSM funding to the cities of Minneapolis and St. Paul and to Mn/DOT for projects such as integrated corridor signal coordination, traffic management center operations and upgrades, and arterial traffic flow improvements through signal system upgrades.

The U.S. DOT's Urban Partnership Agreement program provides a new source of funding to demonstrate innovative approaches. The DOT is providing $133.3 million in Federal funds, which will be matched by local funds for a total program cost of about $190 million.

B.7 CONCLUDING OBSERVATIONS

While the Met Council and Mn/DOT have been leaders in congestion management strategies, congestion continues to grow due to an increasingly dispersed and growing population. According to the Regional Transportation Plan, if current congestion growth is not addressed, the amount of congested metropolitan highways will increase from just over 1,900 lane-miles in 2000 to over 2,500 lane-miles in 2030. The greatest barrier to reducing congestion has been rapid and dispersed population growth.

The need to plan and implement transportation capacity expansion in a fiscally constrained environment has facilitated creativity in congestion management approaches. For example, with little ability to develop additional highway general purpose lane capacity, the Met Council and Mn/DOT worked together to build ramps with bus bypasses and bus only shoulder lanes as a "back door" approach to managing congestion and adding person-throughput capacity to the overall transportation system.

The plans and programs to reduce congestion in the future rely on a strong regional planning process, building multimodal networks, increasing transit, and monitoring these strategies with performance measures and audits. While the region already has some unique congestion management strategies, it also recognizes the need to increase the effectiveness of congestion management strategies to improve mobility throughout the region in a time of rapid population growth.

Appendix C

Orlando Metropolitan Area

C. Orlando Metropolitan Area

C.1 Introduction and Background

The Orlando, Florida metropolitan area has a population of approximately 1.8 million people spread across Orange, Osceola, and Seminole counties. As a major tourist destination, millions more come to visit each year; 47.8 million tourists visited in 2007 alone, further adding to the demand on the regional roadway transportation system. Metroplan Orlando, the MPO for the three-county area, and its partners have concluded that the majority of the metropolitan area's congestion problems are precipitated by highway crashes and other emergencies, rather than day-to-day traffic volumes. As a result, they have focused many of the region's congestion management strategies on reducing nonrecurring congestion after incidents. They also have focused attention on regional strategies to reduce recurring delay on arterial roadways by optimizing signal timing and coordination. These strategies provide an important complement to capacity expansion, which is now funded largely through toll revenue.

As the MPO for the three-county Orlando region, Metroplan provides the forum for local elected officials and transportation experts to work together to improve mobility for Central Florida residents, businesses and visitors. Metroplan's mission is to provide leadership in planning a transportation system consistent with the metropolitan Long-Range Transportation Plan (LRTP), including the adopted Regional Transportation Vision, by engaging the public and fostering effective partnerships. The Vision seeks to develop a system that safely and efficiently moves people and goods through a variety of transportation options to support the region's desires to preserve natural lands, create community centers, conserve energy, and maintain a strong economy. The 19-member MPO Policy Board is comprised of local elected officials and transportation operating agency representatives. The Board structure also creates a regional forum for single jurisdictions and single modes to come together and work toward common goals.

Other agencies playing key roles in congestion management include the Florida Department of Transportation (FDOT) as well as the Orlando-Orange County Expressway Authority and Florida's Turnpike Enterprise, which operate over 100 miles of toll highways throughout the region. These agencies have worked together and with other partners such as LYNX transit, local governments, and incident responders to manage congestion.

C.2 Planning Process

Metroplan has updated the region's LRTP to the year 2025 as an interim step toward a comprehensive LRTP update to the year 2030, an effort that will be completed in late 2009. As part of the LRTP update process, Metroplan, in partnership with LYNX and FDOT, updated the Regional Transit System Concept Plan, which lays out a framework for future expansion of bus and rail transit.

The Metroplan Policy Board has focused heavily on project prioritization and has determined that Management and Operations (M&O) strategies, including Intelligent Transportation Systems (ITS), are a cost-effective method to relieve traffic congestion. The Board annually allocates about $4 million in Surface Transportation Program (STP) funds for M&O projects and programs, in addition to other money. Metroplan has established an M&O Subcommittee, comprised of representatives of multiple agencies, including the cities of Orlando, Maitland, and Kissimmee; Orange, Osceola, and Seminole counties, FDOT, LYNX; and the University of Central Florida.

Metroplan has integrated its congestion management strategies with three other sets of strategies – Intelligent Transportation Systems (ITS), Transportation Demand Management, and Traffic Incident Management – to form the Management and Operations program. Improvements have been proposed in the 2025 LRTP to address issues, including constrained roadway segments and intersections, and some have been programmed in the Transportation Improvement Program (TIP) or placed on the Prioritized Project List. In addition, as an FY 2006/2007 planning activity Metroplan, through the M&O Subcommittee, developed a Strategic Plan for M&O. The end products of these components will be used to develop the new Congestion Management Process (CMP) in the 2030 LRTP.

C.3 Congestion Management Approaches

While the Orlando region is building new highway capacity to address growing travel demand, it also is implementing strategies and technologies to improve traffic flow that do not involve adding new lanes or building new roadways. Particularly noteworthy congestion management activities include incident management and traffic signal coordination. The region also is increasing its focus on transit, tolling, and long-range growth visioning to play a role in congestion management.

Incident Management

Metroplan's assessments indicate that traffic incidents account for more than half of Central Florida's congestion. Further, FDOT has established that each minute required to respond to an incident causes four minutes of congestion. Because incidents, rather than volume, are the main precipitator of congestion, the region has focused its congestion management strategies on incident response and clearing, using interagency partnerships and agreements to coordinate activities and set performance targets.

One example of coordination is the Tri-County Area Open Roads Policy. Established in 2001, this policy is an agreement among FDOT, FHP, the police and fire/rescue officials in Orange, Osceola and Seminole counties, and all 19 municipalities in those counties to clear all incidents from the roadway within 90 minutes after the arrival of the first responding officer. This commitment of all the region's emergency responders is a first for the entire country.

In order to further support rapid clearing of incidents, Metroplan, FDOT and the Florida Highway Patrol (FHP) introduced the "MOVE IT…Yes You Can!" campaign in January 2004. The "MOVE IT…Yes You Can!" campaign is focused on outreach to and education of the public on the need to move vehicles out of the travel lanes if they are involved in a minor traffic accident. By Florida law, drivers must make every reasonable effort to move a disabled vehicle or have it moved so as not to obstruct the regular flow of traffic, as long as the vehicle is moveable and there are no injuries. MOVE IT was developed jointly by local law enforcement, fire and rescue, transportation agencies and private companies as an outgrowth of a Traffic Incident Management Executive Forum held in July 2003.

FDOT plays a significant role in incident management. The agency has a Traffic Operations Group, whose focus is operations and incident management. Traffic Incident Management ("TIM") teams are comprised of representatives from all of the responding agencies and service providers in a particular FDOT District. They review past response actions and explore ways that incident management can be improved and response times reduced on the highways they serve. The TIM teams have a monthly meeting to debrief on the region's major incidents, focusing on lessons learned from the responses to incidents and the effects that incidents have on traffic congestion.

FDOT currently funds Highway Patrol units and personnel dedicated to the I-4 Corridor in the Orlando region. This effort, implemented in 2004 through an interagency agreement, is intended to improve incident response and clearance times as well as overall traffic management. FDOT has conducted a "before and after" study to help document the impacts of the new dedicated patrols on congestion and incidents in the I-4 Corridor. The study found an inverse relationship between number of miles patrolled and number of crashes. It further found that crashes in work zones decreased by 21 percent after troopers started patrolling and that 8 of the 13 identified high-accident locations in the corridor experienced significant decreases in numbers crashes after patrols started.

Another service to help alleviate traffic congestion is the Road Ranger program. Road Rangers assist stranded motorists and facilitate incident clearing with law enforcement and rescue. Metroplan has supported Road Rangers with financial resources through the TIP and MPO work program. Metroplan allocates about $500,000 annually of its Federal STP funds to support the operation of the Road Rangers.

The Orlando-Orange County Expressway Authority supports incident management on its system as well. The Authority began with a study 10 years ago that identified incidents as a critical issue and precipitated the Expressway Management System. This system uses cameras, travel times, variable message signs, 511 traveler information, and dedicated police presence to combat congestion due to incidents, and will soon include a pilot project to provide real-time traffic information on the system.

Finally, various agencies in the Metroplan region use ITS to support incident management, with 230 cameras to help identify incidents and 400 variable message signs to alert travelers to incidents, suggest possible alternate routes, and identify the need to exit early from the expressway.

Traffic Signal Coordination

Within the Metroplan region, there are about 1,500 traffic signals. Control of these traffic signals is split between various jurisdictions. Local and national studies have shown that retiming traffic signals can improve the operations of a corridor (including reduced delays and stops, improved safety, and reduced fuel consumption and emissions) from 5 to 25 percent. For these reasons, agencies within the region have agreed to use FDOT signal phasing standards across all jurisdictions. Furthermore, computer-coordinated traffic signal systems are being deployed in Orange, Osceola, and Seminole counties, including on International Drive in Orange County. Seminole County is complementing this technology by installing more than 20 Variable Message Signs in the vicinity of I-4 interchanges and at the intersections of U.S. 17/92 with both SR 436 and SR 434. These signs will convey real-time traffic information to motorists and can provide detour routing for incidents on I-4. In addition, during 2005, Orange County deployed several similar message signs in the vicinity of I-4 on SR 535, Central Florida Parkway, Sand Lake Road, John Young Parkway, and Lee Road. As of 2007, 67 percent of the region's traffic signals were computer-controlled.

According to Metroplan, *The Traffic Signal Report Card*, developed by the National Transportation Operations Coalition (NTOC) in both 2005 and 2007 to measure how well traffic signals operate on the nation's roadways, reported that the region's overall traffic signal system was performing about 20 to 25 percent more effectively than the nation's systems on average.

Transit and Alternative Modes

The region currently is making attempts to increase transit services to help alleviate congestion and provide more transportation choices. During 2007, FDOT continued to spearhead efforts to bring a commuter rail system to the region. Commissions in Orange, Osceola, Seminole, and Volusia counties, along with the Orlando City Council, unanimously agreed to participate in the project. Local agreements were approved in which each jurisdiction pledged a local contribution to match Federal and state dollars committed for commuter rail. The Central Florida Commuter Rail Commission held its inaugural meeting at METROPLAN ORLANDO in August 2007. Operation of the first phase of commuter rail service is expected to begin in 2010.

Metroplan and FDOT also consider bicycle and pedestrian facilities to be important components of an effective transportation network. Accommodations for pedestrian traffic are incorporated into the overall transportation system, including sidewalks, marked crosswalks, enhanced landscaping for shade, and increased street lighting for safety. Improvements to bicycle facilities have been made as well. Repaving many of the area roads allows for the addition of bicycle lanes, and multi-use trails throughout the region are included in short- and long-term plans. The LRTP proposes to greatly expand the bicycle and pedestrian facility system with an investment of at least $74 million over the next 20 years.

Other ITS Technologies

Like many areas across the country, the Metroplan region employs a transponder-based automated toll collected system. From 2003 through 2007, the number of transponders in use in the region grew by 58 percent, from just over 434,000 to nearly 686,000. Several toll plazas on the region's 100-mile expressway system have been converted to "open road tolling" express lanes, which provide another application of technology. This allows drivers to bypass the cash lane because electronic monitors over the roadway collect the tolls as the E-PASS- or SunPASS-equipped vehicles travel at posted highway speed. As an incentive to use transponders, customers typically pay 25 cents less than cash customers at most toll plazas and exits. Metroplan officials consider open road tolling to be an effective congestion mitigation strategy since it facilitates improved flow and more reliable operations on the toll facilities.

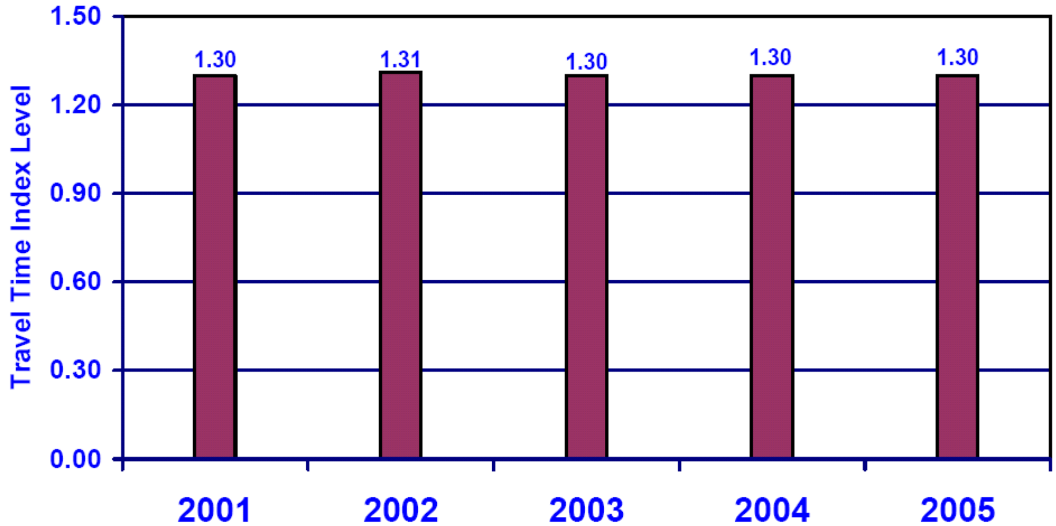
FDOT's "iFlorida" ITS initiative (formally known as "Florida's Surface Transportation Security and Reliability Information System Model Deployment") is an innovative model ITS deployment first awarded in 2003 under an FHWA initiative. The objective of the deployment is to demonstrate the wide variety of operational functions that are enabled or enhanced by a surface transportation security and reliability information system. Among other things, Federal grant funding will support tests of new automated travel-time monitoring and variable speed limits. For example, FDOT has replaced 22 static speed limit signs on I-4 near Orlando with variable speed limit signs. These give FDOT the capability to adjust speed limits to match current traffic conditions and more effectively manage traffic when congestion or incidents occur.

C.4 Performance Measurement

Over the next 20 years, the Orlando metropolitan region's population is expected to increase by between 1.4 million and 2.2 million, an increase of at least 2 percent per year. Meanwhile, tourist growth is increasing at an even faster rate – 5 percent per year – more than doubling the current tourist levels by 2025. To prepare for these changes, the region, through Metroplan and its partners, is employing various performance measures to gauge the success of congestion management efforts. Metroplan staff also has an annual "discussion" with their

Policy Board about the Texas Transportation Institute (TTI) report on urban congestion levels ("Travel Time Index")[4] and impacts of the region's M&O initiatives on those levels (see Figure 3.1).

Figure C.1 Orlando Metropolitan Area Travel Time Index
2001-2005



Source: Texas Transportation Institute – 2007 Urban Mobility Report.

Data collection is an important piece of the region's congestion management process. Data is mainly gathered on expressways and major highways and primarily in Orange County. In 2002, FDOT led the establishment of the "Central Florida Consortium" by signing a memorandum of understanding with 12 local and regional partner agencies and organizations in the greater Metroplan region. The Consortium is intended to be a "one-stop shop" for traffic information across the member organizations. The Consortium agreement provides a framework and guidelines for highway operating agencies related to data; promotes coordinated decision-making; and promotes information sharing on ITS initiatives related to planning and development, funding and operations.

The iFlorida initiative also is supporting improved data collection and performance measurement. Under the iFlorida umbrella, the Expressway Authority acts as data collector, processor, and clearinghouse for both its own and certain FDOT initiatives in central Florida. FDOT currently is testing the data collection to ensure accuracy. When this phase is completed, travel-time data will be

[4] The Travel Time Index (TTI), developed by the Texas Transportation Institute, is the ratio of the travel time during the peak period to the time required to make the same trip at free-flow speeds. A value of 1.3, for example, indicates a 20-minute free-flow trip requires 26 minutes during the peak period.

publicized through monthly performance reports. FDOT is tracking incident clearing time on I-4 and I-95 through simple manual spreadsheets that will eventually become more formal and automated. All of these efforts are making data collection more comprehensive so that the region can improve its congestion management process.

Metroplan annually produces, with assistance from a variety of agencies and planning partners, a "Tracking the Trends" report. Among other things, this document provides an overview of the condition of the Orlando area's transportation system by evaluating the trends that have occurred over the past several years on the area's highway, transit, aviation, rail, and bicycle and pedestrian systems. Information for the report is provided by a variety of state and regional agencies covering all modes of transportation as well as the environment, economic development, education, and other issues.

In the 2007 Tracking the Trends report (published in February 2008), Metroplan noted that although the region's population growth, gas consumption, vehicle miles traveled, and the number of registered vehicles had all grown in recent years, the actual travel-time index has remained the same during that period at 1.3. This may be due to effective congestion management strategies and mobility improvements, such as computerized signals, electronic toll collection, and transit. For example, in the period from 2003 to 2007, the total number of passengers on the LYNX transit system increased by 20.7 percent and the number of passengers on the I-Ride trolley system increased by 14.3 percent. Similarly, Metroplan reported that traffic signal coordination has resulted in a decrease in annual person-hours of travel delay in the region from 210,000 in 2001 to 189,000 in 2005 as a result of expanded traffic signal coordination, based on estimates in *The 2007 Urban Mobility Report.*

Historically, the Metroplan region has used levels of service to guide the congestion management process. In the last few years, however, the M&O subcommittee of Metroplan has focused on variables related to incidents as indicators, such as number of Road Rangers service assists per year and change in high-crash locations on expressways and arterials. The performance measure-based congestion management approach also encourages the questions, "are we making the right investments? And what can we do differently to combat congestion?"

Metroplan sponsors a telephone survey of residents in the three county metro area on transportation issues, conducted by the University of Central Florida's Institute for Social and Behavioral Sciences. In the last surveys, two of the highest-priority items, each described as "very important" by two-thirds or more of respondents were: 1) improved coordination of traffic signals; and 2) clearing highway accidents more quickly. These findings support Metroplan's focus on incident management as well as traffic signal coordination as critical congestion management strategies.

The reporting of data helps Metroplan and FDOT build credibility with the public. Data helps quantify the realized benefits of projects and programs, although there is still much more that Metroplan would like to do in this area. The public perception of performance measures often focuses on travel-time delays, a measure now communicated more effectively through technology rather than "low-tech" methods such as telephone hotlines or commercial radio traffic reports. Both Metroplan and FDOT recognize the need to continue instrumenting the transportation system to collect data to measure performance and ensure that that customers are being served effectively.

C.5 PARTNERSHIPS AND PUBLIC OUTREACH

Given the regional impact of congestion from both commuters and visitors, regional cooperation is critical to improving transportation in Central Florida. Metroplan recognizes that no single jurisdiction or organization can solve the region's transportation challenges. Through collaboration, Metroplan works to achieve its vision for a world-class transportation system. In particular, the interagency partnerships discussed above are allowing the region to manage incidents much more effectively as well as to achieve benefits through improved traffic signal timing and coordination.

The Orlando region undertakes public outreach efforts to engage residents and stakeholders around issues such as congestion. One example of these efforts is Metroplan's initiative called "How Shall We Grow?" This initiative, launched in 2006, is a collaborative effort in a seven-county area that includes the Metroplan region as well as four surrounding counties falling within the jurisdiction of the East Central Florida Regional Planning Council. How Shall We Grow? has engaged elected officials, staff from state, regional, and local organizations, business and civic leaders, and the public in establishing a vision for the region's future through the year 2050. An alliance of regional leaders from the public and private sectors was motivated to undertake the initiative by the recognition that continued rapid growth could seriously threaten the livability and economy of the region if key issues including transportation, land use, the economy, and the environment were not addressed in a coordinated manner. For example, transportation modeling conducted in support of the initiative found that the average automobile travel speed in 2050 under a trend growth scenario could drop to 21 mph, compared to 34 mph today, or 26 mph under a "centers" scenario consisting of high-density urban centers connected by rail transit.

Between March 2006 and August 2007, nearly 20,000 Central Florida residents answered the question about how the region should grow through a series of community meetings, presentations, and surveys. The result is the Regional Growth Vision, which is a shared vision for how the region can grow between now and 2050, when the population is expected to more than double from 3.5 million to 7.2 million residents. Going well beyond the scope and timeframe of a traditional long-range transportation plan, the initiative identified preserving the natural environment and promoting smart, quality growth as top priorities and identified transportation principles to support these priorities. Of the six guiding principles identified during the outreach process, two directly relate to the

Metroplan Orlando mission and vision: Preserving open space, recreational areas, farmland, water resources, and regionally significant natural areas, and providing a variety of transportation choices. Metroplan believes this collaborative public engagement process is helping shape the selection and implementation of congestion management strategies and other key transportation choices for the region, including regional transit concepts.

C.6 FUNDING

Metroplan Orlando's operating budget is drawn from three primary sources: Federal grants, state grants, and local per capita assessments. In FY 2008, Metroplan allocated about $264,000 for congestion management and M&O-related planning activities. Federal Surface Transportation Program (STP) and state funds are used for congestion management programs such as Road Rangers. Certain special projects receive additional Federal funds. For example, FDOT's "iFlorida" ITS initiative recently received a $10 million U.S. DOT grant plus $10 million in state funds to expand ITS facilities and data management and integration capabilities.

With fast growth and below-average gas taxes – 24 cents a gallon in state and local gas tax versus 26 cents on average statewide and an allowable maximum of 30 cents – the Orlando region has turned to toll roads to meet its growing travel demand without draining resources needed for maintaining and improving the existing system. While Orange County's five-year road building budget is about $200 million, the Orlando-Orange County Expressway Authority's budget is $1.1 billion, nearly seven times as much, with $400 million of that coming from toll revenue in excess of operating and maintenance costs. At this time, all of these toll revenues are dedicated to toll road development, operations, and maintenance.

With growth in toll facilities and their use, there has been a steady increase in the amount of annual toll revenues collected. This increase from FY 2002/2003 through FY 2006/2007 is illustrated in Table 3.1.

Table C.1 Toll Revenues in Orlando Metro Area
2002/2003 to 2006/2007

Revenues	2002/2003	2003/2004	2004/2005	2005/2006	2006/2007
SR 408	$73,100,000	$78,700,000	$80,400,000	$85,112,000	$86,503,000
SR 417	$72,800,000	$82,700,000	$92,400,000	$101,994,000	$108,523,000
SR 429	$7,200,000	$9,200,000	$10,500,000	$14,523,000	$20,741,000
SR 528	$40,700,000	$46,500,000	$51,500,000	$54,678.000	$56,403,000
Florida's Turnpike	$22,600,000	$25,900,000	$29,300,000	$32,314,000	$33,511,000
Osceola Parkway	$7,100,000	$8,600,000	$11,400,000	$11,628,000	$11,440,000
Total	$223,500,000	$251,600,000	$275,500,000	$300,249,000	$317,121,000

Source: Orlando-Orange County Expressway Authority and Florida's Turnpike Enterprise.

Another local source of revenue is the Rental Car Surcharge. Florida has a substantial rental car industry, primarily due to its tourism industry, and the Orlando Metropolitan Area has the largest rental car market in the country. As a result, rental vehicles have a major impact on the levels of traffic congestion in the area, particularly on those roadways in the vicinity of the Orlando International Airport and the tourist attractions. For 2006/2007, the region's total Rental Car Surcharge revenue was about $38 million.

The region's counties also impose a Local Infrastructure Sales Tax, which provides a significant revenue source for capital expenditures. Osceola and Seminole counties impose a 1-cent sales tax, while Orange County imposes a half-cent sales tax. In addition, counties can implement up to 12 cents of a Local Option Gas Tax (LOGT). As of 2008, Osceola and Seminole counties have implemented 7 cents of their LOGT and Orange County has implemented a 6-cent tax.

C.7 Concluding Observations

Congestion resulting not only from local travelers but also from tourists is a serious issue in the Orlando metro region. Working collaboratively, state and regional agencies have largely focused on incident management to address nonrecurring congestion. The region also is continuing its efforts to take a multijurisdictional approach, including signal timing initiatives on several multijurisdictional corridors. Tolling technology is largely being used to finance new highway capacity.

Congestion management in the Orlando region also is beginning to integrate transit as a strategy, although transit still does not have a dedicated regional funding source. However, issues such as the potential for falling into nonattainment in air quality and economic vitality could drive the region to place even more emphasis on and transit and other alternative modes, as well as land use strategies for managing travel demand. In particular, Metroplan's LRTP process, informed by the Regional Growth Vision, is examining transportation-land use options across many dimensions.

Transportation officials in the Orlando region note that effective leadership is needed to champion the issues that the public need to understand in order to effectively plan for the future and address congestion. Furthermore, public support for projects and programs is driven largely by the methods used and quality of information conveyed about congestion, and the historically limited availability of data to show the return on investments from programs and projects represents an obstacle to gaining this support. FDOT and Metroplan Orlando are working to gather more robust data on system performance and investment impacts, as well as finding better ways to share information and data through a range of media.

Appendix D

San Diego Metropolitan Area

D. San Diego Metropolitan Area

D.1 Introduction and Background

> *"Ask anyone what's the biggest problem in San Diego, and you'll probably hear "traffic." However, if we have learned anything in the last decade, it's that we can't build our way out of congestion."*
>
> – From the 2030 San Diego Regional Transportation Plan

The San Diego metropolitan area contains an estimated 2008 population of 3 million, and is expected to add another million people by 2030. The region's transportation system is planned and managed primarily by the San Diego Association of Governments (SANDAG) in partnership with local and state agencies. SANDAG is a forum for regional decision-making comprised of 18 cities and the San Diego County government. Functioning as the region's metropolitan planning organization (MPO), SANDAG has proven to be a national leader in congestion management. SANDAG's current congestion management processes, beginning prior to the Intermodal Surface Transportation Efficiency Act (ISTEA) of 1991, have continued to evolve with subsequent Federal congestion management process requirements under the Transportation Equity Act for the 21st Century (TEA-21) to provide for the safe and effective management and operation of new and existing transportation facilities through the use of demand reduction and operational management strategies. SANDAG has accomplished much within the congestion management arena, particularly in the integration of congestion management into the regional planning process; the integration of demand management and capacity management; technological initiatives; innovative funding approaches; and the comprehensive use of performance measures.

A Board of Directors composed of mayors, municipal council members, and county supervisors from each of the region's 19 local governments governs SANDAG. Supplementing these voting members are advisory representatives from Caltrans as well as the region's two major transit operators. As the MPO, SANDAG allocates millions of dollars each year in local, state, and Federal funds for the region's transportation network. SANDAG also develops the Regional Transportation Plan (RTP), which crafts the region's long-range vision for buses, light and heavy rail, highways, major streets, bicycle travel, walking, goods movement, and airport services. SANDAG also bears responsibility for transit planning, funding allocation, project development, and construction.

D.2 PLANNING PROCESS

The vision of the 2030 San Diego RTP is to have many convenient transportation choices. The RTP's vision for transportation supports the region's comprehensive strategy to promote smarter, more sustainable growth. The RTP has seven policy goals, including livability, mobility, efficiency, accessibility, reliability, sustainability, and equity.

California State Proposition 111, passed by voters in 1990, established a requirement that designated congestion management agencies in urban areas prepare and regularly update a Congestion Management Program (CMP). While the requirements of San Diego's congestion management program are not identical to the congestion management requirements of ISTEA or TEA-21, there are many similarities, including the designation of transportation management agencies and the use of performance measures, evaluation, strategy selection, and project implementation. While SANDAG follows both Federal and state guidelines in its congestion management approaches, it continues to use the term "congestion management program" rather than the Federal nomenclature.

SANDAG's CMP is updated every two years and is an integral aspect of the RTP, falling within its Systems Management section. The purpose of the CMP is to monitor roadway congestion and assess the overall performance of the region's transportation system, and to identify specific strategies and improvements to reduce traffic congestion and improve the performance of a multimodal transportation system. The CMP's scope goes beyond traditional transportation strategies and includes integration with land use decision-making, including incentives and requirements for mitigating the impacts of new development projects, as well as better coordinating land use and transportation planning decisions.

Key CMP highlights include:

- **Promote Nontraditional Strategies –** The focus is on the use of near-term, lower-cost alternative transportation strategies to address congestion. These strategies are grouped into several areas, including transportation demand management, transportation system management, and design guidelines. These strategies can be used in preparing deficiency plans, mitigating new development impacts, and supporting other local planning activities.
- **Project Mitigation –** For all major development projects, SANDAG encourages the use of appropriate CMP strategies to mitigate significant impacts on CMP roadways, as determined by local agencies. Through more effective mitigation of traffic impacts associated with new developments, it may be possible to reduce future congestion. The CMP can assist agencies with this responsibility by offering a range of mitigation strategies that can be applied to unique development project impacts and varying local conditions.
- **Deficiency Plan Development Process –** Deficiency Plans are required by CMP statute when roadway level of service (LOS) falls below the minimum

CMP standard of LOS "E." The plan proposes remedial action necessary to address the deficiency, including low-cost and near-term improvements to address congestion. If RTP recommendations will not eliminate the deficiency, the deficient roadway segment is included in either a subregional planning study or addressed in an individual area or corridor deficiency plan.

- **CMP Compliance Monitoring –** The CMP recommends that SANDAG take a more proactive stance in working with local jurisdictions and transportation operators to monitor implementation of the CMP and to fine tune the CMP in response to evolving local needs.

SANDAG also has prepared a supplementary report, *Congestion Mitigation Strategies*, that provides additional guidance on transit and land use strategies. The report provides a "toolbox," a collection of over 40 strategies that local jurisdictions have the option of pursuing to reduce local and regional traffic congestion. Strategies are arranged in five categories, including land use, transit, travel demand management, transportation systems management, and capital strategies. In addition to the toolbox, the report highlights the Trip Reduction Ordinance (TRO) framework for local jurisdictions. The TRO contains mandatory and voluntary measures for reducing travel demand. Trip Reduction Guidelines provide methodologies for incorporating selected congestion mitigation strategies into the traffic impact assessment process and estimating their effectiveness in terms of associated trip reduction potential. According to SANDAG, research and experience has shown that travel demand management programs are most effective when reinforced by local trip reduction ordinances and guidelines.

D.3 Congestion Management Approaches

SANDAG's approaches to congestion management include a range of travel demand management strategies, as well as technological strategies to improve traffic flow.

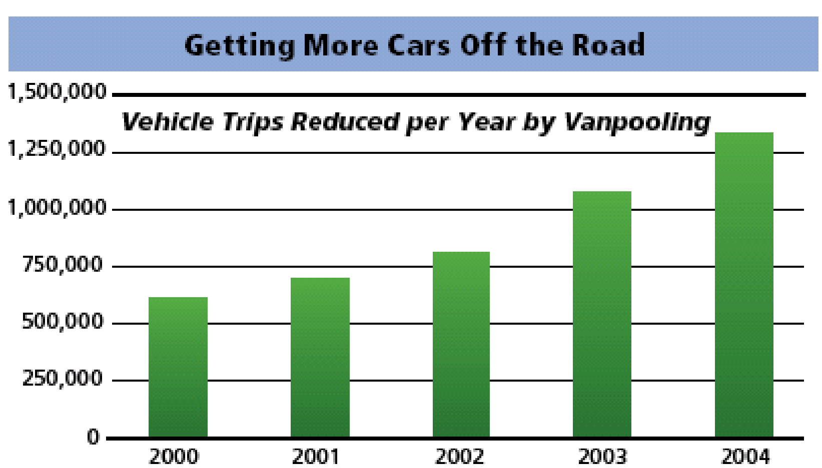
Travel Demand Management

TDM focuses on reducing trips on the transportation system, especially during rush hours when the highest traffic congestion occurs. The RTP encourages the development of viable travel choices that include using transit (including train, bus, trolley, and Coaster commuter rail), carpooling, vanpooling, biking, and walking. One recently completed transit project that is expected to decrease highway congestion is the Sprinter, a commuter train that provides service along side the heavily traveled SR 78 corridor.

Since 1995, SANDAG has operated a regional TDM program called RideLink. RideLink is SANDAG's regional commuting services program that assists employers, employees, and students with identifying and using alternative ways to commute to work or school. RideLink programs include: Employer Outreach, Regional Vanpool Program, Telework/Flex time, Carpool Matching, Guaranteed Ride Home Program, School Services, and the Regional Bicycle Locker Program. The Employer Outreach Program assists employers in developing value-added commuter programs by offering tax benefits to employers and employees and offering technical and outreach assistance. The Telework/Flex Time Program offers employers assistance in developing telework, flex time, and compressed work-week programs to help reduce commute trips. The Guaranteed Ride Home Program encourages transit trips by offering a free taxicab or 24-hour car rental up to three times a year for registered carpool, vanpool, and transit riders in the chance that they miss their ride. As of October 2007, there are 1,027 active registrants. School services include a Walking School Bus Program to increase walking and decrease parent-driven trips to school, and the SchoolPool program that helps parents form carpools for school transportation. The Regional Bicycle Locker Program provides commuter cyclists with secure facilities to park bicycles. Program participants either pay a one-time key deposit fee or use the on-demand lockers at various major transit centers. This allows commuters to use both transit and bicycles to commute to and from work. As of October 2007, there were 559 lockers at 47 different sites available to commuters.

RideLink maintains a database of commuters to provide matches for the Carpool Matching Program and the Regional Vanpool Program. The vanpool program contracts with vendors to provide the vehicles, maintenance, and insurance and also provides $400 per year subsidy to vanpool groups. In 2006, the RideLink staff responded to almost 20,000 inquiries for information about ridesharing, transit, and bicycling by telephone or web site. As of October 2007, the program had 572 participating vanpools that reduced nearly 114 million vehicle miles in FY 2007 (Figure 4.1).

Figure D.1 Vehicle Trips Reduced per Year by Vanpooling in the San Diego Region



Source: SANDAG.

Systems Development

The RTP describes priorities for regional infrastructure improvements to provide more travel choices to help alleviate congestion. The existing transit network provides 33 million miles of annual transit service, carrying over 70 million total annual passengers. SANDAG's two regional transit providers, the Metropolitan Transit System (MTS) and North Country Transit District (NTCD), provide bus, rail, and trolley services throughout the region.

Bus services include The BREEZE, which in over 30 years of service has grown to an annual ridership of more than 10 million and serves between 35,000 to 40,000 passengers daily. Coaster commuter trains operate between the North Country and San Diego, carrying thousands of commuters per day. In 2006, the Coaster provided more than 1.5 million trips. One recently completed transit project that is expected to decrease highway congestion is the Sprinter, a commuter train that provides service alongside the heavily traveled SR 78 corridor. MTS also operates a trolley in San Diego that covers 54 miles on three routes, seven days per week. By continuing to develop transit services, SANDAG hopes to better manage congestion.

ITS Initiatives

SANDAG makes extensive use of advanced technology to support congestion management. Intelligent Transportation Systems (ITS) programs include the Advanced Traveler Information System (511), electronic payment systems, and transit management systems. SANDAG manages the 511 web site that provides traffic, transit, RideLink, and bicycling information. The FasTrak program allows solo drivers to pay tolls from prepaid accounts via transponders mounted on the inside of the vehicle's windshield, thus, alleviating congestion at toll facilities. ITS initiatives within the transit systems improve service performance and increase ridership through vehicle tracking, transit traveler information, and automated fare payments.

Early efforts undertaken by SANDAG included the completion of the region's first ITS Strategic Plan as part of SANDAG's 2020 RTP, adopted in 2000 and currently being updated. The 2030 RTP contains proposed actions for SANDAG to take to support the ITS Strategic Plan and the RTP goals of mobility, reliability, and efficiency. One of these actions is to coordinate development and implementation of ITS Strategic Plan projects within the San Diego region so that the network is interoperable, compliant with the national and regional ITS architecture, and delivers aspects of integrated performance management. Another action is to regularly update the 511 systems and services to stay current with changes in technology and availability of transportation information.

The Intermodal Transportation Management System Network is a communications system that forms the backbone for the exchange of information between ITS systems in the region. Freeway Management Systems enable Caltrans to coordinate freeway operations with adjacent regions through installation of computer hardware, software, loop detectors, ramp meters, variable message signs, and cameras. Arterial Traffic Management Systems provide software and hardware to coordinate traffic signal timing and optimize traffic flow across jurisdictions.

Table 4.1 summarizes current ITS applications in the San Diego region.

Table D.1 Summary Description of ITS Applications in SANDAG Region

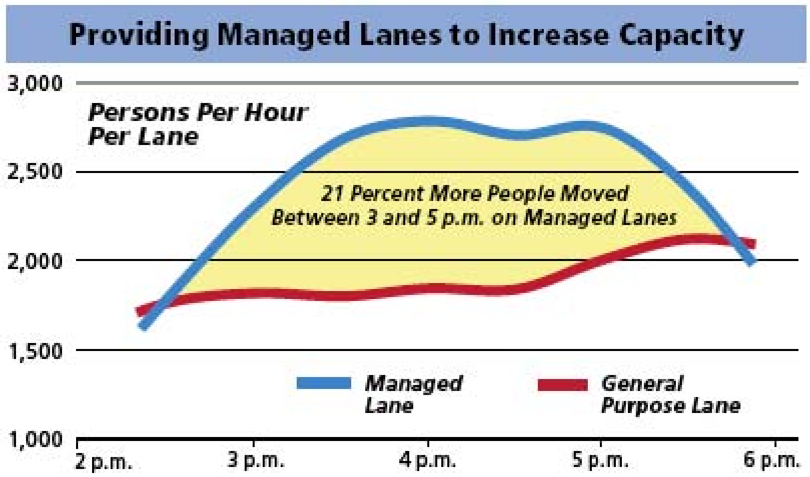
Systems	Description	Basic Functional Services/Data Types	Stakeholder Agencies
IMTMS Network	Regional communications network, including leased and agency-owned communications resources that form the backbone for the exchange of information between ITS systems in the region.	Services: System integration, security, communications, regional network management, etc. Data: All types of data, including both data exclusive to a particular project and data shared between multiple ITS projects.	All agencies
Freeway Management System	Focused around the Advanced Transportation Management System (ATMS) being deployed by Caltrans District 11, it is the core of freeway management, including the use of cameras, changeable message signs, and vehicle detection sensors.	Services: Field device (cameras, CMS, vehicle detection stations) control/management, incident/event management, incident response, resource management, etc. Data: Freeway speeds, incidents, video, sign messages, etc.	Caltrans, CHP, cities, transit and emergency services
Regional Arterial Management Systems	Focused around the Regional Arterial Management System (RAMS), and comprised of two basic tiers: 1. Interjurisdictional signal coordination/ management. 2. Local advanced traffic and event management. In addition, the Mission Valley Advanced Transportation Management and Information System (ATMIS) is viewed as an initial implementation of RAMS Tier 2 for architecture purposes. MV ATMIS functions will be incorporated and expanded on as part of RAMS Tier 2.	Services: Signal timing/control, interjurisdictional signal timing, regional timing plan implementation, field device (cameras, CMS, vehicle detection stations) control/management, incident/event management, incident response, resource management, etc. Data: Signal status, timing, local incidents/events, arterial cameras, vehicle sensors, and message signs.	Cities, Caltrans, local law enforcement, and transit agencies
Transit Management Systems	Comprised of several transit management systems in the region for purposes of fleet management, enhanced schedule performance, improved fare payment, and improved interagency coordination.	Services: Fleet management, vehicle tracking, emergency alerts, transit schedule and arrival information, transit traveler information, automated fare payment, etc. Data: Transit vehicle locations, vehicle status, schedule performance adherence, real-time information displays at stops, dispatch/vehicle text messages, etc.	Transit agencies, some local cities, and emergency services during safety-related incidents

Systems	Description	Basic Functional Services/Data Types	Stakeholder Agencies
Traveler Information Management Systems	The public sector will provide a common interface for private information service providers to obtain selected information from the IMTMS Network.	Services: Portal for public sector transportation information on IMTMS Network to private sector information providers, data translation, data filtering, etc. Data: Freeway/roadway speeds, incidents, announcements, transit schedule information, and next stop arrival, etc.	Private sector traveler information providers

Transportation Systems Management

The region has high-occupancy vehicle (HOV) lanes on the I-15 freeway that reduce delay for carpools and transit during peak travel periods. HOV lanes are increasingly being converted into managed lanes with variable pricing, or high-occupancy toll (HOT) lanes, to increase capacity, encourage alternative mode use, and raise revenue on the most congested highways. (HOT lanes are limited-access lanes in which carpools, vanpools, and buses have first priority and travel for free, while other vehicles gain access by paying a fee.) SANDAG's first HOT lanes initiative is the I-15 FasTrak® program, which has been operating since 1996 on the I-15 express lanes from the I-15/State Road (SR) 163 junction to SR 56. The lanes are managed through variable pricing to maintain free-flow conditions even during rush hours, and revenues are used to support transportation improvements within the corridor, such as express bus service. As shown in Figure 4.2, the FasTrak® program has demonstrated the ability to move thousands more people during rush hours in a managed lane than in a comparable general purpose lane. The 2030 RTP also includes plans for additional HOT lanes on the major north-south freeways, including Interstates 5, 15, and 805 that build upon the success of the I-15 program. Funded by a Corridor Mobility Improvement Account award of $432 million, work began in 2007 to further expand the I-15 managed lanes and HOV lanes on I-805 near the Sorrento Mesa employment center.

Figure D.2 Increased Capacity Due to Managed Lanes in the San Diego Region



Source: Caltrans Monitoring Station at I-15 and Mira Mesa Boulevard, September 2002 Weekday Averages.

Recently, SANDAG and Caltrans have moved in the new direction of addressing congestion management at a corridor level, using real-time data that is shared and exchanged. The corridor management approach is important because it manages the entire freeway rather than pushing the problem (the bottleneck) further up the highway into another area. The 2007 updated version of the RTP calls for the implementation of Integrated Corridor Management (ICM) on I-15, the primary artery from inland northern San Diego County to downtown San Diego. The I-15 corridor has been serving a growing number of interregional trips using managed lane systems and multimodal transport options. As of the spring of 2008, Caltrans has conducted analysis, modeling, and simulation for plan review, plan approval, and site selection for this corridor. Using ITS and real-time data, information is gathered to monitor conditions on the corridor and report on its status to the public. Integrated Management web services allow the public to access information such as area congestion, freeway events, performance measures, transit locations, and signal timing. This coordinated management approach is a collaborative effort among multiple partners, including the North County Transit District, Metropolitan Transit System, California Highway Patrol, and Caltrans. Data is shared among these agencies and organizations to improve the management and operation of the corridor and to monitor and report on conditions.

D.4 Performance Measurement

An important dimension of maximizing the efficiency of the region's existing transportation system is using performance measures to manage the system. Although the region's surface transportation elements – freeways, roads, and transit systems – can be managed separately, they are interdependent and require a comprehensive multimodal management focus to achieve SANDAG's mobility goals. SANDAG refers to this comprehensive approach as "Integrated Performance Management" (IPM).

The RTP contains a comparison of the regional performance measures, of which many are used to measure congestion (see Table 4.2). Performance measures are used in the RTP to plan for a scenario that, assuming reasonably expected revenue sources, decreases traffic congestion in the region. The goals and performance measures are compared using 2006 data and projected forecasts for both plan scenarios – one with a reasonably expected future revenue source and one with "No Build" conditions. Key highway performance indicators used to evaluate and improve congestion include speed, volume, vehicle hours of delay, and vehicle miles traveled (VMT). With a reasonably expected revenue source, performance measures are expected to improve many of the indicators of congestion over current measures. Future indicators that are predicted to improve are percent of peak-period travel conditions that are congested, carpool and transit speed, and work trip mode splits during peak periods (less driving alone).

Table D.2 Regional Performance Measures

Goals and Performance Measures	Current (2006)	No Build (2030)	Reasonably Expected Scenario (2030)
Mobility			
• Average work trip travel time (in minutes)	27	34	30
• Average daily travel time (in minutes)		21	18
• Average work trip travel speed by mode (in mph)	17		
– Auto	27	20	23
– Carpool	28	23	31
– Transit	10	10	12
Accessibility			
• Work/school trips within 30 minutes in peak periods	61%	53%	56%
Reliability			
• Congested peak-period travel conditions	32%	54%	30%
• Congested daily travel conditions	19%	36%	19%
• Daily vehicle delay per capita (minutes)	5.09	13.07	5.80
Livability			
• Percent of daily trips within one-quarter mile of a transit stop	68%	64%	67%
• Work trip mode split (peak periods)			
– Drive alone	81.1%	81.3%	77.8%
– Carpool	10.8%	11.2%	13.2%
– Transit	6.4%	5.8%	7.3%
– Bike/Walk	1.7%	1.7%	1.7%
• Average trip distance (daily VMT divided by total regional trips)	6.44	6.75	6.76

Goals and Performance Measures	Current (2006)	No Build (2030)	Reasonably Expected Scenario (2030)
Sustainability			
• Smog-forming pollutants (tons per year) per capita	0.020	0.005	0.005
• Systemwide VMT (all day) per capita	27.65	29.16	28.54
• Transit passenger miles (all day) per capita	0.59	0.56	0.72

SANDAG's updated 2007 RTP includes changes in performance measures to better evaluate congestion. The "daily vehicle miles traveled" indicator has been changed to "daily vehicle miles per capita" to allow for more accurate comparison of vehicle miles traveled as population grows. For similar reasons, "daily transit passenger miles" becomes "daily transit miles per capita." New measures for the 2007 updated plan include the percentage of daily trips within one-quarter mile of a transit stop and the average trip distance. These new measures are targeted to meet the Livability goal and provide for a measurement of the relationship between land use and transportation performance.

For the region's roadway networks, SANDAG coordinates the annual collection of average daily traffic volumes with Caltrans and local jurisdictions. Through the Congestion Management Program, SANDAG collects roadway level of service data every two years. For most freeways, traffic volumes and speed data are automatically collected by Caltrans through loop detectors embedded underneath the pavement and other emerging vehicle detection technologies. For local streets and roads, traffic volume counts are gathered manually and are not always performed on a regular basis.

Tools have been developed to improve the ability of gathering, tracking, and analyzing real-time data. The statewide Freeway Performance Monitoring System (PeMS), developed by the California Partners for Advanced Transit and Highways (PATH) and the University of California at Berkeley, has the ability to measure freeway speeds, delays, and reliability for the regional freeway system. PeMS provides the ability to estimate various performance indicators and measurements based on freeway volume and lane occupancy data through web-based applications. Data is collected by in-pavement or aboveground automated detection devices and is transmitted every 30 seconds. This monitoring system also has the ability to classify vehicles at traffic monitoring stations to evaluate vehicle mix and weights. A ramp metering interface has provided the ability to monitor and analyze ramp volumes. These monitoring improvements are supplementing the SANDAG performance monitoring program by providing SANDAG with the ability to better identify and prioritize transportation corridor improvements as well as to monitor, track, and evaluate the effects and impacts of transportation capital project investments over time.

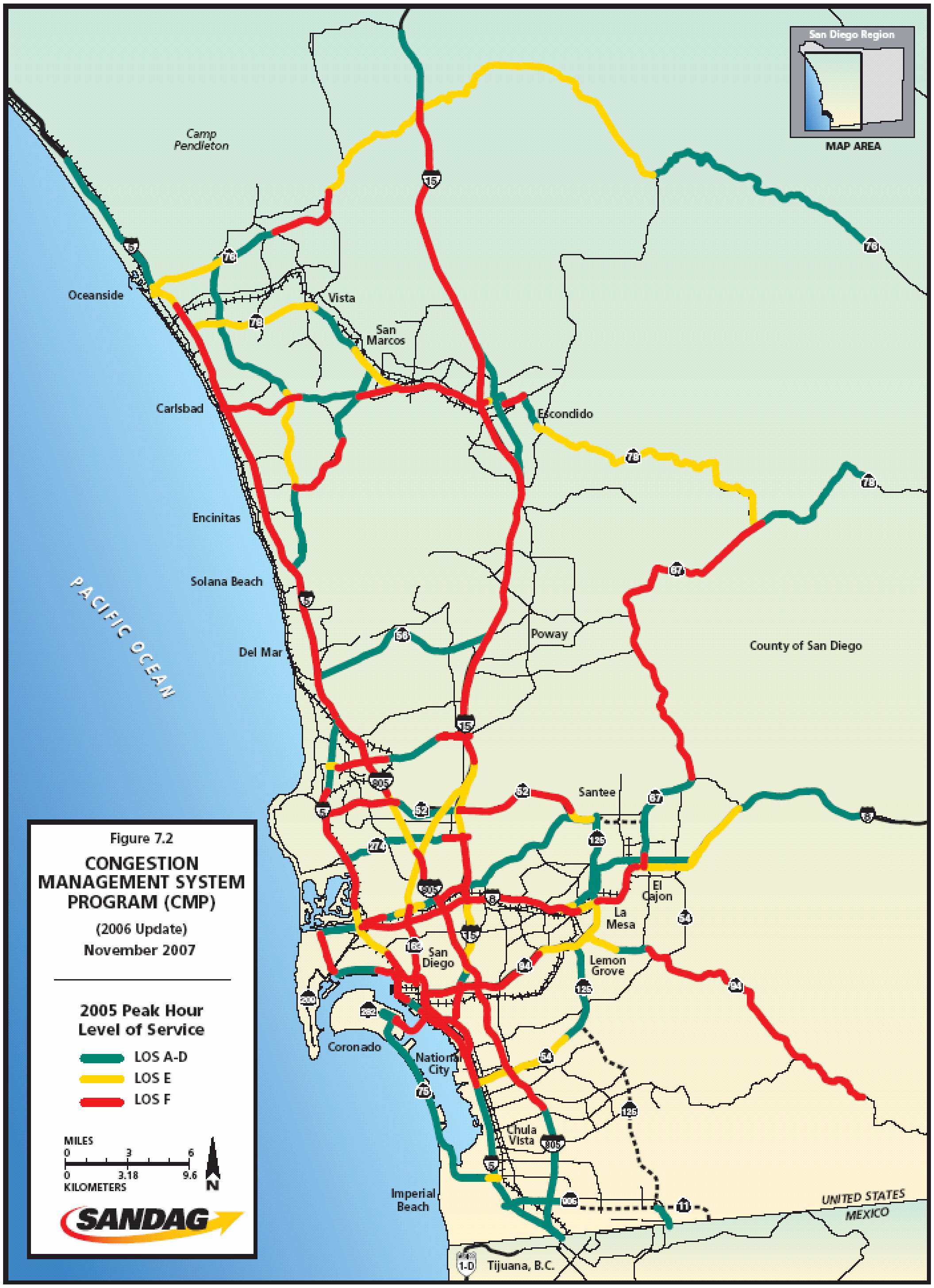
SANDAG has recently begun using data collected through PeMS for monitoring in support of the Regional Comprehensive Plan, rather than using model-based travel times only. Work is ongoing to assess the quality of the data gathered through PeMS. Planned improvements to PeMS recently initiated by SANDAG in coordination with Caltrans and regional transit agencies include the development and integration of transit and arterial modules. Additional enhancements will include reporting of an estimated travel-time reliability factor. These features will allow PeMS to perform as a multimodal performance measurement and evaluation tool for the San Diego region.

Performance monitoring also helps track how well the San Diego regional transportation system achieves the goals and recommendations of the 2030 RTP. Average daily traffic, vehicle occupancy and classification, and transit ridership data are made available through SANDAG's on-line Regional Information System.

A challenge associated with the regional performance monitoring system is to evaluate these diverse data and provide ongoing reporting of the transportation system's performance in an easy-to-understand format for decision-makers and the general public. SANDAG publishes reports and provides newsletters to the public that display information on the performance of the transportation system (see Figure 4.3). One of these outreach efforts is the development of the Regional Comprehensive Plan Annual Performance Monitoring Report. The Report relays information to the public about transportation trends and progress on meeting regional mobility goals and transportation investment decisions in relation to regional land use, energy, and environmental strategies. SANDAG also publishes annual updates to highlight recently completed projects and to report on projects funded by TransNet, the local option sales tax that funds transportation improvements. By providing this information to the public, SANDAG hopes to increase public support and accountability. The repeated voter passage of TransNet is an indicator of the high level of public support for transportation projects.

A further challenge is documenting the success of San Diego's congestion management strategies on a comprehensive basis in the face of the region's rapid population growth and consequent increase in overall regional congestion levels. To address this, SANDAG is seeking to refine its performance measures to more accurately reflect the relationship between congestion and population growth, thereby improving its ability to gauge success in congestion management and produce credible information for the public and policy-makers.

Figure D.3 SANDAG Highway Network Peak Hour Level of Service
2005



Source: SANDAG.

D.5 PARTNERSHIPS AND PUBLIC OUTREACH

The San Diego region addresses many of its congestion management goals through collaboration with local, state, and Federal entities, as well as with stakeholders in the public and private sectors. SANDAG officials stated that all of their congestion management initiatives are collaborative, and that they work with various partners in all stages of a project.

SANDAG is working with the U.S. DOT, Caltrans, and transit service providers as a pioneer site in the Integrated Corridor Management program. SANDAG also works with Caltrans on many projects that are part of the congestion management process. Within systems management, their collaboration includes HOT lanes, development of corridor and systemwide deficiency plans, and performance monitoring efforts. The San Diego Transportation Management Center (TMC) integrates Caltrans' Traffic Operations and Maintenance in a unified communication and command center that provides communications, surveillance, and computer infrastructure to coordinate transportation management on state highways.

As an association of governments and local elected officials, SANDAG works with the Metropolitan Transit System and North County Transit District, which operate transit services in the region, on programs and plans. A 2003 state law consolidated all of the roles and responsibilities of SANDAG with many functions of the previously existing transit operators, enabling SANDAG to assume transit planning, funding allocation, project development, and construction in the San Diego region in addition to its ongoing transportation planning responsibilities and other regional roles. These interdependent and interrelated responsibilities facilitate a more streamlined, comprehensive and coordinated approach to planning for the region's future.

SANDAG works with many local agencies, including San Diego Regional Traffic Engineer's Council (SANTEC) and California Travel Parks Association. For example, SANTEC aids SANDAG with their congestion management strategies by developing supplemental traffic impact study guidelines. SANDAG also brings in key stakeholders to work on project development teams with internal agency staff in the congestion management process. SANDAG also works with local governments. As part of their Regional Land Use Planning and Coordination Department, SANDAG takes an active role in reviewing a wide variety of developmental plans or studies under their Intergovernmental Review and Development Project Review efforts.

SANDAG's Public Involvement Program is designed to inform and involve the region's residents in the decision-making process on issues such as growth, transportation, environmental management, air quality, energy, economic development, and public safety. SANDAG encourages public participation in a variety of forums: SANDAG Board meetings; Transportation Committee meetings; Regional Planning Committee meetings; and other technical working groups and ad hoc committee meetings, including issues on congestion management.

SANDAG's monthly electronic newsletter, "rEgion," is a venue for the public to stay informed and involved. SANDAG also conducts public outreach for many projects and holds public workshops to review project and policy alternatives. SANDAG believes that its efforts to engage the public on a continuing and broad basis have created broad support for SANDAG's congestion management initiatives.

D.6 FUNDING

SANDAG has created local revenue sources to support its congestion management efforts. The primary funding source for SANDAG congestion management is TransNet, the half-cent local sales tax. This sales tax, repeatedly supported by voters, provides funding for both system expansion and system management, including demand management. Since 1988, TransNet has been instrumental in expanding the transportation system, reducing traffic congestion, and bringing critical transit projects to life. Table 4.3 provides a snapshot of the funding provided by TransNet and other funding for specific projects that alleviate congestion.

Table D.3 TransNet-Funded Projects Underway

Project	Total Cost (in Millions)	TransNet	State/ Federal/ Other	Completion Date
I-15 Managed Lanes (Middle)	$428	14	414	2008
SR 52 East and Westbound Lanes (between Santo Road and Mast Boulevard)	$57	54	3	2008
I-5 HOV Lanes (Del Mar Heights to Manchester)	$75	28	47	2008
Super Loop Transit Project	$39	39	0	2008
I-5 North Coast Corridor (Environmental Effort)	$50	24	26	2009
SR 52 (SR 125 to SR 67)	$599	192	407	2010
Trolley Blue and Orange Lines Vehicle and Station Upgrades (Phase I)	$55	7	48	2010
Mid-City Rapid Bus	$43	18	25	2011
I-805 Corridor (Environmental Effort and BRT)	$144	108	36	2011
I-15 Managed Lanes (North)	$250	130	120	2011
I-15 Manages Lanes (South)	$467	47	420	2012
I-15 BRT and FasTrak	$144	92	52	2012
SR 76 (Melrose Drive to I-15)	$377	354	23	2013
Mid-Coast Corridor Transit Project (Trolley)	$1,246	48	1,198	2014

As part of a recent TransNet ordinance, local governments will begin collecting exactions on new development for the Regional Transportation Congestion Improvement Program (RTCIP) in 2008. The RTCIP provides for the collection of $2,000 per new dwelling unit to ensure future development contributes its proportional share of the funding needed to pay for the Regional Arterial System and related transportation facility improvements. The Transportation Development Act (TDA) 0.25 percent sales tax funds also helps decrease traffic congestion by exclusively funding operating and capital expenditures for transit purposes. Other local revenues include toll roads and street and road general funds.

The Federal government is strongly encouraging transportation agencies to initiate user fee programs to help address congestion. SANDAG's system expansion includes HOT lanes to raise revenue for capacity expansion as well as transit service improvements. The net revenues generated by the I-15 FasTrak® program currently fund the Inland Breeze express bus service in the corridor.

SANDAG also leverages state funds for congestion management. State Transportation Improvement Program (STIP) funds leverage revenue anticipated from the infrastructure bond program and the Highway Safety, Traffic Reduction, Air Quality, and Port Security Bond Act of 2006 (Proposition 1B). State funds also include State Transit Assistance (STA) funds, Traffic Congestion Relief Program (TCRP) funds, and the state gas tax. Through robust local funding sources combined with strong state and Federal support, the RTP foresees that the San Diego region will achieve reasonably expected funding rather than a constrained budget in the future.

D.7 Concluding Observations

While the San Diego region has successfully been employing congestion management practices, there have been challenges along the way. One challenge in combating traffic congestion is the region's increasing population. SANDAG expects that traffic congestion will generally worsen over time, unless actions are taken to directly address travel demand and provide options to get people out of their single occupant vehicles. Another barrier has been finding adequate funding.

With recent funding opportunities at both the state and Federal levels, SANDAG has placed greater emphasis on project outcomes, goals, and performance. These initiatives also have placed greater emphasis on public and private collaboration and partnerships, which one SANDAG project manager considers a step in the right direction with regards to finding adequate funding opportunities while maintaining and measuring system performance. The completion of the ICM project and development of the Corridor System Management Plans are examples of such efforts.

SANDAG has pursued and facilitated many opportunities to improve its congestion management strategies. SANDAG officials believe the most beneficial opportunity has been Federal partnerships with the State. The collaboration between Federal and state agencies, between state and regional, and between regional and local have all been beneficial to the congestion management process. Most of SANDAG's congestion-related projects entail working with regional partners to successfully deliver a variety of regional projects with TransNet funding, which has given the region the opportunity to leverage more state and Federal money.

Appendix E

References

E. References

Short Citation	Title	Date	Author/ Source	Brief Description and Web Link
AASHTO 2003	AASHTO Freight-Rail Bottom Line Report	2003	Cambridge Systematics, Inc. for AASHTO	Primarily focuses on freight-rail system, including infrastructure, current and future demand, and investment needs. Includes some highway and truck statistics such as truck forecasts. http://freight.transportation.org/doc/FreightRailReport.pdf
AASHTO 2007	AASHTO Congestion Management Workshop	2007	AASHTO	A one-day workshop, cosponsored by FHWA, was held in September 2007 to discuss CM best practices. Includes presentations from Milwaukee (host), San Francisco, Hampton Roads, Seattle, Philadelphia, and FHWA. http://downloads.transportation.org/2007SCOP/ AASHTO%20Workshop%20Agenda.pdf
AASHTO 2007	Virtual Weigh-in-Motion: A "WIM-win" for transportation agencies	2007	AASHTO WIM Lead States Team	Best practices and challenges in VWIM deployment at the five "lead states": Florida, California, Nevada, Indiana, and North Dakota. http://tig.transportation.org/?siteid=57&pageid=1003
Abdel-Rahim 2004	Handbook of Transportation Engineering – Chapter 18	2004	Abdel-Rahim, Ahmed. (Kutz, Myer, ed.)	Explains different uses of ITS to reduce vehicle delay caused by incidents. Contains a lot of best practices but does not quantify their benefits.
ACT/FHWA 2004	Mitigating Traffic Congestion – The Role of Demand-Side Strategies	2004	Association for Commuter Transportation, *et al.* for FHWA	Articulates a framework for understanding contemporary efforts to manage demand and improve the performance and efficiency of transportation systems. The document provides extensive examples of programs already underway in a variety of application settings, including over 25 in-depth case studies from across the country. http://www.ops.fhwa.dot.gov/publications/mitig_traf_cong/index.htm
AHUA 2004	Unclogging America's Arteries: Effective Relief for Highway Bottlenecks	2004	Cambridge Systematics for American Highway Users' Alliance	This study examines how much worse gridlock will become at major U.S. bottlenecks if no improvements are made, and estimates the benefits of improving the worst bottleneck locations, including time, lives, and air pollution. http://www.highways.org/pdfs/bottleneck2004.pdf

Short Citation	Title	Date	Author/ Source	Brief Description and Web Link
AHUA 2005	Are We There Yet? A Report on Summer Traffic Bottlenecks and Steps Needed to Ensure that Our Favorite Vacation Destinations Remain Accessible	2005	American Highway Users' Alliance	Identifies major seasonal (summer) bottlenecks. Estimates delays but not benefits of bottleneck reduction strategies. http://www.highways.org/pdfs/travel_study2005.pdf
Alba and Beimborn 2004	Relationship Between Land Use Patterns and Highway Widening	2004	Alba, C. and E. Beimborn (Center for Urban Transportation Studies, UW-Milwaukee)	Identifies two critical land use factors that lead to highway widening: street connectivity and land use density, and examines how these affect arterial volumes and widening thresholds. Highway Capacity Manual methods are used. A case study is presented from Tallahassee, Florida. http://www.uwm.edu/Dept/CUTS//lu/carlos.pdf
APTA 2006a	New Vehicle Market data for bus operators in the United States	2006	American Public Transportation Association	Contains bus capital cost statistics. http://www.apta.com/research/stats/bus/#A4
APTA 2006b	New Vehicle Market data for rail operators in the United States	2006	American Public Transportation Association	Contains rail capital cost statistics. http://www.apta.com/research/stats/rail/#A4
Banerjee 2001	Preliminary Evaluation Study of Adaptive Traffic Control System	2001	Banerjee, F. (City of Los Angeles Department of Transportation)	From 1999 to 2001, the City of Los Angeles Department of Transportation developed and deployed an Adaptive Traffic Control System (ATCS) that automatically adjusts traffic signal timing at 375 intersections. Intersections in the Mar Vista and Brentwood areas of the city were selected for the evaluation. "Before" and "After" data were collected at the selected intersections over four days during daylight hours under clear, dry weather conditions. http://www.its.dot.gov/jpodocs/repts_te/14321.htm
Bartholomew 2005	Integrating Land Use Issues into Transportation Planning: Scenario Planning Summary Report	2005	Bartholomew, K., for FHWA	Summarizes the practice of regional land use and transportation scenario planning activities from around the U.S. http://faculty.arch.utah.edu/bartholomew/SP_SummaryRpt_Web.pdf
Bell 2001	Oregon Green Light CVO Evaluation	2001	Bell, C. (Transportation Research Institute, Oregon State University)	Evaluation of Oregon's "Green Light" electronic screening system implemented at 21 weigh stations estimates cost savings to the State, travel-time and fuel savings to the trucking industry. http://www.itsdocs.fhwa.dot.gov/jpodocs/repts_te/13597.html

Short Citation	Title	Date	Author/ Source	Brief Description and Web Link
Birst and Smadi 2000	An Evaluation of ITS for Incident Management in Second-Tier Cities: A Fargo, ND Case Study	2000	Birst, S. and A. Smadi	This paper describes the results of a simulation study to determine the impact of a freeway management system on incident-related congestion in Fargo, North Dakota. The study also investigates the benefit of coordination between the freeway management system and an arterial management system to enable adaptive signal control based on the demands of the additional traffic diverted from the freeways during an incident.
BTS undated	Freight Data and Statistics: Economic Impact on Transportation (web site)		Bureau of Transportation Statistics	Provides a brief overview of freight's economic impact. http://www.bts.gov/programs/freight_transportation/html/transportation.html
Burris and Stockton 2004	Hot Lanes in Houston – Six Years of Experience	2004	Burris, M. W. and Stockton, W. R., Journal of Public Transportation, Volume 7, No. 3	This research documents the findings of six years of experience with two HOT lanes in Houston, Texas. This includes an examination of the daily number of paying customers on the HOT lanes, benefits of the HOT lanes, socioeconomic and commute characteristics of HOT lane users, and their mode of choice when electing not to use the HOT lane. http://www.nctr.usf.edu/jpt/pdf/JPT%207-3%20Burris.pdf
Bushman and Berthelot 2004	Estimating the Benefits of Deploying Intelligent Transportation Systems in Work Zones	2004	Bushman, R., and C. Berthelot	In this study, the QuickZone traffic analysis tool was used to compare traffic conditions with and without the provision of real-time work zone traffic information at a representative two-mile work zone on I-95 in North Carolina. The system evaluated was designed to monitor traffic conditions in real-time, determine expected traffic delays, and advise motorists of current delays and alternate route information using portable dynamic message signs (DMS) and an Internet web site.
Cal Poly 2000	Final Report: Continuation Study to Evaluate the Impacts of the SR 91 Value-Priced Express Lanes	2000	Sullivan, E. (Cal Poly State University)	Final report for the continuation phase of a Caltrans and U.S. DOT-sponsored study to evaluate the impacts of the value-priced express lanes located in the median of the Riverside Freeway (State Route 91) in Orange County, California. http://ceenve3.civeng.calpoly.edu/sullivan/SR91/final_rpt/FinalRep2000.pdf
CDOT 1985	State of Colorado Access Control Demonstration Project	1985	Colorado Department of Highways	Study of access management benefits (running times and safety).
CDOT 2001	Colorado Value Express Lanes Feasibility Study	2001	Colorado Department of Transportation	The Colorado Value Express Lanes Feasibility Study is a CDOT effort to examine the desirability and feasibility of implementing Value Express Lanes on the North I-25 and U.S. 36 High-Occupancy Vehicle (HOV) lanes and other locations in the Denver region.

Short Citation	Title	Date	Author/ Source	Brief Description and Web Link
Cervero 1990	Transit Pricing Research – A Review and Synthesis	1990	Cervero, R. (University of California)	Broad discussion of transit pricing schemes, and associated ridership elasticities.
Chatterjee 2008	Curbside Delivery of Freight by Trucks in Downtowns of Small- and Medium-Sized Urban Areas	2008	Chatterjee, A., et al. (ITE Journal, January 2008)	Discussion of congestion management through freight pick up and delivery strategies in smaller downtowns. Includes case studies and strategies, but no impacts data.
Commission 2007	Evaluation of the Potential Applicability of HOV, HOT, and BRT Lanes	2007	Buxbaum, J. and C. Kopp (Cambridge Systematics) for Nat'l Surface Transportation Policy and Revenue Study Commission	Discusses potential applicability of managed lane strategies.
Cornell/RPI 1999	Evaluation of Advanced Information Technology at Peace Bridge	1999	Cornell University and Rensselaer Polytechnic Institute	Travel-time savings of a transponder-based IT application at Peace Bridge, a major border crossing between New York and Ontario. http://www.benefitcost.its.dot.gov/its/benecost.nsf/ID/ AA1E5E111EE629AD852569610051E2D3?OpenDocument&Query=Home
CREATE Web Site	CREATE Program, various documents (Web Site)		Chicago Department of Transportation	Travel-time, economic, and air quality improvements resulting from the Chicago Region Environmental and Transportation Efficiency (CREATE) Program, which involves the installation of 6 rail-rail grade separations, 25 highway-rail grade separations, and various other infrastructure improvements. http://www.createprogram.org/press.html
CRS 2007	Surface Transportation Congestion: Policy and Issues	2007	Congressional Research Service	Congressional primer includes history and legislative history of congestion trends (rail, transit, and road). Review of measures, trends, economic impact, and strategies to mitigate. http://assets.opencrs.com/rpts/RL33995_20080206.pdf
CS 2003	Planning Truck-Only Lanes: Emerging Lessons from the Southern California Experience	2003	Cambridge Systematics	Discusses preliminary truck-lane studies for SR-60 and I-710 in Southern California and lessons from those studies, including balancing limited access with needed demand, time-of-day issues, and other demand modeling concerns. http://www.ltrc.lsu.edu/TRB_82/TRB2003-002048.pdf
CS and Battelle 2005	An Initial Assessment of Freight Bottlenecks on Highways	2005	Cambridge Systematics and Battelle for FHWA	Identifies highway system bottlenecks serving large volumes of truck traffic, and quantifies direct congestion costs. http://www.fhwa.dot.gov/policy/otps/bottlenecks/

Short Citation	Title	Date	Author/ Source	Brief Description and Web Link
CS/DOE 2006	Analysis of Market-Based Approaches for Reducing Fuel Consumption – Work-Based TDM Strategies	2006	Cambridge Systematics for U.S. Department of Energy	Estimated VMT, fuel, and GHG savings from extending EPA's Best Workplaces for Commuters program nationwide.
CS/FHWA 2005	An Initial Assessment of Freight Bottlenecks on Highways	2005	Cambridge Systematics for FHWA	This white paper attempts to identify and quantify highway freight bottlenecks and the associated cost to users on a national scale. The inventory defines bottlenecks by the constraint type, roadway type, and freight route type. http://www.fhwa.dot.gov/policy/otps/bottlenecks/index.htm
CS/FHWA 2006a	Linking Congestion Management to Operations – Hampton Roads Planning District Commission	2006	Cambridge Systematics for FHWA	This case study presents an example of the Hampton Roads MPO's approaches for improving congestion management by strengthening the relationship between CMP and operations. http://www.plan4operations.dot.gov/
CS/FHWA 2006b	The Relationship Between Congestion Management and the Planning Process	2006	Cambridge Systematics for FHWA	This case study investigates best practices of how congestion management processes (CMP) are related to the transportation planning process in three MPOs. The perspectives of the planning process explored in this case study are data presentation (Seattle), project prioritization (Detroit), and stakeholder involvement (Dallas-Ft. Worth). http://www.plan4operations.dot.gov/
CS/FHWA 2006c	Using CMP Tools to Advance NEPA Documentation	2006	Cambridge Systematics for FHWA	This case study illustrates how MARC developed a clearer way of showing how capacity expansion projects had gone through the CMP by linking NEPA studies with the CMS Toolbox. http://www.plan4operations.dot.gov/
CS/FHWA 2006d	Congestion Management Processes Workshop: February 22, 2006 Meeting Notes	2006	Cambridge Systematics for FHWA	FHWA held a workshop on CMPs in February 2006. The workshop notes include numerous anecdotes from participants about CMPs in various metro areas – Kansas City, Hampton Roads, Detroit, Dallas, Seattle, Albany, North Jersey are highlighted. http://www.plan4operations.dot.gov/
CS/FHWA 2006e	Congestion Management Processes Peer Exchange and Case Studies – Overview	2006	Cambridge Systematics for FHWA	Overview of the 2006 FHWA workshop on CMP. http://www.plan4operations.dot.gov/
CS/FHWA 2007	A Guidebook on the Congestion Management Process in Metropolitan Transportation Planning	2007	Cambridge Systematics for FHWA and FTA	Provides guidance on how to develop and implement an objectives-driven CMP. Includes brief case studies/examples from Atlanta, Philadelphia. http://www.plan4operations.dot.gov/

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CS/FHWA 2007	ITS Impact Relationships	2007	Cambridge Systematics for FHWA	Best estimates of the impacts of various ITS/operations strategies on congestion and delay, for use in the Highway Economic Requirements System (HERS) Operations Postprocessor module.
CS/FHWA 2008a	An Interim Guidebook on the Congestion Management Process in Metropolitan Transportation Planning	2008	Cambridge Systematics for FHWA	Describes basic steps of a CMP and an objectives-driven CMP approach. Includes examples from Atlanta and Kansas City. Includes inventory of performance measures.
CS/FHWA 2008b	Statewide Reference for Linking Planning and Operations	2008	Cambridge Systematics for FHWA	This primer is designed to raise awareness of the benefits and opportunities for coordinating planning and operations activities within state DOTs. Includes minicase studies of specific state agencies – GA, MN, KS, OR, PA, WA; as well as Kansas City and Hampton Roads.
CS/FTA 2005	New Starts Economic Benefits Evaluation. Task 2 – Peer Approaches: Regional Economic Analysis. Attachment A: Literature Review	2005	Cambridge Systematics, Inc. for Federal Transit Administration	Reviews 12 modeling studies of the impacts of transit investment on the regional economy. Some studies report benefits resulting from highway user benefits (congestion reduction) as well as transit user benefits.
CS/Metra 2008	Long-Term Economic Benefits of Metra Investment: UP-West and UP-Northwest Corridors	2008	Cambridge Systematics for Metra (draft report)	Estimates regional economic benefits of two commuter rail improvement projects. Includes an estimate of highway user delay and VMT reductions based on mode shifting.
CS/MnDOT 2002	Twin Cities HOV Study	2002	Cambridge Systematics for Minnesota DOT	Evaluation of HOV lanes in Minneapolis and impacts of opening lanes to general traffic. http://www.hovworld.com/publications_assets/MnDOTfull_study.pdf
CS/MnDOT 2006	I-394 MnPass Technical Evaluation, Final Report	2006	Cambridge Systematics for Minnesota DOT	This report presents technical findings from impact of HOT Lanes on I-394, known locally as MnPASS, which represents the first deployment of HOT lane strategies in Minnesota and one of the first in the United States that dynamically adjusts pricing levels in response to varying traffic conditions. http://www.mnpass.org/pdfs/394mnpass_tech_eval.pdf

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CS/NCHRP 2005	National Site Visits on Transportation and Growth	2005	Cambridge Systematics for NCHRP (Project 8-36, Task 40)	Contains descriptions of projects linking transportation and land use. Cites New Jersey DOT corridor planning projects. http://environment.transportation.org/environmental_issues/land_use_sg/docs_reports.aspx
CS/NCHRP 2006	NCHRP 3-68, Guide to Effective Freeway Performance Measurement	2006	Cambridge Systematics for NCHRP	Discusses traffic data collection and performance measurement for monitoring and evaluation of congestion, reliability, and other factors on freeways. http://www.trb.org/trbnet/projectdisplay.asp?projectid=822
CS/NYCDOT 2007	Congestion Mitigation Commission Technical Analysis: Telecommuting Incentives	2007	Cambridge Systematics for New York City DOT	Summarizes a set of case studies reviewed for this study and reports the telecommuting participation levels, the frequency at which an employee telecommutes, the entity that administers the telecommuting incentive program, and the incentives that the entity offers. https://www.nysdot.gov/portal/page/portal/programs/repository/Tech%20Memo%20on%20Telecommuting.pdf
CS/NYCEDC 2007a	Congestion Pricing Commission Technical Analysis: Task 2- Night Delivery Incentives and Regulations as Alternatives to Pricing	2007	Cambridge Systematics for New York City DOT	Estimates potential congestion impacts of shifting delivery times in Manhattan. Includes case studies of value pricing programs in NY/NJ, offpeak program at POLA/LB, 1997 commercial vehicle variable pricing initiative at the Tappan Zee Bridge, London's Congestion Pricing Program, and the 1996 Atlanta Olympic Games. https://www.nysdot.gov/portal/page/portal/programs/repository/Tech%20Memo%20on_Night%20Delivery%20Incentives.pdf
CS/NYCEDC 2007b	Congestion Pricing Commission Technical Analysis: Task 3 – Telecommuting Incentives as an Alternative to Pricing	2007	Cambridge Systematics for New York City DOT	Estimates potential for telecommuting to reduce VMT and congestion in Manhattan. Includes nationwide review of telecommuting impacts.
CS/ODOT 2007	The Future of Tolling in Oregon: Understanding How Varied Objectives Relate to Potential Applications	2007	Cambridge Systematics for Oregon DOT	Discussion of tolling applications, including implementation issues. http://www.oregon.gov/ODOT/HWY/REGION2PD/docs/Area5/TollinginOregonReport.pdf
CUTR 2001	Lee County Variable Pricing Project: Evaluation Report	2001	Center for Urban Transportation Research	Evaluation of variable pricing on the Midpoint and Cape Coral toll bridges in Lee County, Florida. Bridge users are offered a toll discount during select offpeak hours as an incentive to change trip times from peak to offpeak hours. http://www.cutr.usf.edu/its/Evaluation%20Report%202000.pdf

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CUTR undated	TDM Clearinghouse		Center for Urban Transportation, University of South Florida	Includes evaluations of FL TDM programs and case studies, research, reports, etc. http://www.nctr.usf.edu/clearinghouse/
DMJM 2003	Syracuse Signal Interconnect Project: Before and After Analysis Final Report	2003	DMJM Harris for New York State DOT	In response to Onondaga County not meeting air quality standards in 1993, the City of Syracuse implemented the Signal Interconnect Design Project. The project standardized 145 intersections within the City of Syracuse and optimized the signal timing in an attempt to reduce automobile emissions by creating a more efficient network. Includes helpful tables on vehicle speed, signal delay, and vehicle delay.
Downs 1992	Stuck in Traffic: Coping with Peak-Hour Traffic Congestion	1992	Downs, A.	The book in its entirety addresses several congestion-fighting strategies, including supply expansion, peak-hour pricing, behavioral remedies, and land use/growth management. Chapter 3, Supply Strategies: Coordinated timing of traffic signals along arterial roads can increase travel speeds by 12 to 25 percent by replacing older signals with computer-controlled signals.
Dumke and Doyle 2001	Intelligent Transportation Systems in Work Zones: Leveraging the Internet and Wireless Communications	2001	Dumke, L. R. and T. E. Doyle	This project evaluated work zone incident management systems designed to improve safety and incident response times during reconstruction at the "Big I" interchange in Albuquerque, New Mexico. A construction traffic management center was developed to monitor work zone traffic conditions, assess incidents, and dispatch police, wreckers, and on-site courtesy patrols.
Dunn 2005	Traffic Control Systems Handbook	2005	Gordon, R. L., and W. Tighe (Dunn Engineering Assoc.)	The Traffic Control Systems Handbook serves as a basic reference in planning, designing, and implementing traffic control systems.
DVRPC 1991	Public Transportation Renewal as an Investment: The Economic Impacts of SEPTA on the Regional and State Economy	1991	Urban Institute and Cambridge Systematics for Delaware Valley Regional Planning Commission	Analysis of the economic impacts of reducing or shutting down Southeastern Pennsylvania Transportation Authority (SEPTA) service in the Philadelphia region.

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Eddington 2006	The Eddington Transport Study: Transport's Role in Sustaining the UK's Productivity and Competitiveness		Eddington, R., for U.K. Department for Transport	This study in the United Kingdom, probably the largest single study ever undertaken on this topic, reports that on average a 10 per cent increase in public capital infrastructure stock increases overall gross domestic product (GDP) by about two percent, and that a five percent reduction in travel time for all business travel could generate around 2.5 billion pounds of cost savings.
EDR 2005	The Cost of Congestion to the Economy of the Portland Region	2005	Economic Development Research Group for Portland Business Alliance, Metro, Port of Portland, and Oregon DOT	Results of a future scenario analysis performed for Portland, Oregon; includes background on relationships of congestion to freight movements and economy. Pegs cost to regional economy at $800 million annually to 2025. Includes case studies of businesses impacted by congestion.
EDRG 2004	Chicago Metropolis 2020: Freight Plan	2004	Economic Development Research Group	EDR Group applied its transportation economic development impact system (TREDIS) to evaluate how changes in traffic levels, speeds, and costs would affect logistic costs for the area's industries and subsequent regional economic growth. The analysis estimated metrowide economic impacts in terms of jobs, earnings, and business sales. Finding: "Congestion delay costs Chicago businesses, truckers, and commuters over $4 billion per year." http://www.chicagometropolis2020.org/documents/MetropolisFreightPlan.pdf
EDRG/FHWA 2001	Using Empirical Information to Measure the Economic Impact of Highway Investments	2001	Economic Development Research Group and Cambridge Systematics for FHWA	Includes a literature review of the impact of highways on economic development. Primary focus is rural rather than urban.
Eliasson 2006	Cost-benefit Analysis of the Stockholm Congestion Charging System	2006	Eliasson, J. (Transek AB)	Economic evaluation of the welfare impacts of congestion pricing in Stockholm.
Evans 2005	Capacity and Cost Comparisons of Rapid Transit Modes	2005	Evans, J., for ITE Annual Meeting	Uses several available sources to compile and compare capital and operating costs of various transit modes. www.ite.org/meetcon/2005AM/Evans_Tues.pdf
Ewing 2005	Generalizing from Sacramento: What Is Really Possible	2005	Ewing, R.	Examines potential for reducing VMT from land use strategies; cites Bartholomew work on VMT reduction in scenario planning exercises.
Ewing and Cervero 2001	Travel and the Built Environment – Synthesis	2001	Ewing, R., and R. Cervero	Synthesis and bibliography of findings on relationships between land use and travel behavior.

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FDOT 2008	State Specifications and Estimates Office: Estimates Section	2008	Florida DOT	Provides highway construction cost estimates. http://www.dot.state.fl.us/estimates/LaneMileCosts/LaneMilecosts.htm
FHWA 1999	Greenhouse Gas Control Strategies: A Review of "Before-and-After" Studies	1999	EEA and Cambridge Systematics for FHWA	This white paper presents a summary review of the GHG impacts of transportation strategies, including TDM and TSM for which impacts are measured in terms of VMT or fuel consumption.
FHWA 2004	Freight Transportation: Improvements and the Economy	2004	Federal Highway Administration	Summarizes the results of FHWA's work on the economic benefits of transportation improvements. Benefit-cost analysis was conducted to improve estimation of the benefits of transportation improvements. Both short-term and long-term benefits are documented. http://ops.fhwa.dot.gov/freight/freight_analysis/improve_econ/
FHWA 2004	Signalized Intersections: Informational Guide	2004	Federal Highway Administration	Chapter 10: alternative intersection treatments: discusses such alternatives as continuous flow intersections, jughandles, grade separations, etc. http://www.tfhrc.gov/safety/pubs/04091/10.htm
FHWA 2005a	Improving Mobility and Accessibility with Managed Lanes, Pricing, and BRT: Conference Proceedings	2005	Federal Highway Administration	Covers a variety of topics, including project status, deployment, and evaluation. http://ops.fhwa.dot.gov/publications/12hovsysconf/index.htm
FHWA 2005b	Traffic Congestion and Reliability: Trends and Advanced Strategies for Congestion Mitigation	2005	Cambridge Systematics and Texas Transportation Institute for FHWA	Provides a snapshot of congestion in the United States by summarizing recent trends in congestion, highlighting the role of travel-time reliability in the effects of congestion, and describing efforts to reduce the growth of congestion. http://ops.fhwa.dot.gov/congestion_report/
FHWA 2007	Regional Concept for Transportation Operations	2007	Federal Highway Administration	A Regional Concept for Transportation Operations (RCTO) is a management tool to assist in planning and implementing management and operations strategies in a collaborative and sustained manner. Developing an RCTO helps partnering agencies think through and reach consensus on what they want to achieve in the next three to five years and how they are going to get there. The purpose of this document is to explain what an RCTO is, the development of its elements, and its applicability. Interspersed with examples from Phoenix and Denver. http://www.ops.fhwa.dot.gov/publications/rctoprimer/index.htm

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FHWA 2007a	Active Traffic Management: The Next Step in Congestion Management	2007	FHWA with AASHTO and NCHRP, for International Technology Scanning Program	A scanning study examining congestion management programs and policies in Europe. The scan team observed that transportation agencies in Denmark, England, Germany, and the Netherlands, through the deployment of congestion management strategies, are able to optimize the investment in infrastructure to meet drivers' needs. Strategies include speed harmonization, temporary shoulder use, and dynamic signing and rerouting. http://international.fhwa.dot.gov/pubs/pl07012/atm_eu07.pdf
FHWA 2007b	Traffic Bottlenecks: A Primer	2007	Cambridge Systematics for FHWA	Overview of strategies to mitigate congestion caused by bottlenecks, with focus on low-cost solutions. http://ops.fhwa.dot.gov/publications/bnprimer/index.htm
FHWA 2007c	Combating Bottlenecks! A Sampling of Successful Efforts Nationwide (Web Site)	2007	Federal Highway Administration	Capsule descriptions of bottleneck relief projects throughout the country, including discussion of prioritization processes, low-cost alternatives, and both physical and operational improvements. http://www.ops.fhwa.dot.gov/bn/successful_efforts/index.htm
FHWA 2008a	Regional ITS Architecture Examples (Web Site)		Federal Highway Administration	The examples on this page illustrate how some states and regions are using the regional ITS architecture to link planning and operations. Examples: Hampton Roads, Kansas City, Chicago, Anchorage, Salt Lake City. http://www.plan4operations.dot.gov/reg_its_ex.htm
FHWA M&O	Regional Transportation Systems Management and Operations (Web Site)		Federal Highway Administration	This web site contains resources related to all aspects of transportation systems management and operations, including links to documented benefits. A comprehensive list of publications is included. http://www.plan4operations.dot.gov/reg_trans_sys.htm
FHWA MMP	FHWA Mobility Monitoring Program report, Monitoring Urban Freeways	2004	Cambridge Systematics and Texas Transportation Institute for FHWA	The Mobility Monitoring Program is an effort by FHWA to track and report traffic congestion and travel reliability on a national scale. The program uses archived traffic detector data that were originally collected for traffic operations purposes. The program started in 2001 (with an analysis of 2000 data) in 10 cities. In 2004, the program has grown to include nearly 30 cities with about 3,000 miles of freeway. The program tracks three congestion measures (travel-time index, percent congested travel, and delay) and two travel reliability measures (buffer index and planning time index). http://tti.tamu.edu/documents/FHWA-HOP-05-018.pdf

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GAO 2003	Congestion Pricing Has Promise for Improving Use of Transportation Infrastructure	2003	General Accountability Office	GAO statement for the record addresses: 1) the potential benefits that can be expected from pricing congested transportation systems, approaches to using congestion pricing in transportation systems, and the implementation challenges that such pricing policies pose and 2) examples of projects in which pricing of congested transportation systems has been applied to date, and what these examples reveal about potential benefits or challenges to implementation. http://www.gao.gov/new.items/d03735t.pdf
GAO 2007	Transportation Challenges Facing Congress and the Department of Transportation	2007	Government Accountability Office	Includes an estimate of the costs of congestion across all modes. "According to Department of Transportation estimates, congestion costs Americans roughly $200 billion each year."
GAO 2008	Freight Transportation: National Policy and Strategies Can Help Improve Freight Mobility	2008	Government Accountability Office	Reviews: 1) factors that contribute to constrained freight mobility and their effects in areas with nationally significant freight flows and 2) approaches to address freight mobility in those areas and the challenges decision-makers face in implementing those approaches. http://www.gao.gov/new.items/d08287.pdf
Giuliano et al 2005	The Terminal Gate Appointment System at the Ports of Los Angeles and Long Beach: An Assessment	2005	Giuliano, G., T. O'Brien, P. Dell'aquila, S. Hayden (University of Southern California)	This paper presents an assessment of a California law requiring terminal operators at the ports of LA-Long Beach to either extend terminal hours from 45 to 70 per week or implement an appointment system for trucks. http://www.metrans.org/nuf/documents/Giuliano_OBrien.pdf
HI 2007	More Than One-Third Say Traffic Congestion is a Serious Problem in Their Community	2007	Harris Interactive	Just over one-third (37 percent) say that traffic congestion is a serious problem in their community, while one-quarter say traffic congestion is a serious problem that is not being addressed. Twelve percent say it is a serious problem that is being addressed. Just under two in five (39 percent) say traffic is a moderate problem and 21 percent say it is not a problem at all. This is definitely a case of region playing a role. Just one-quarter (26 percent) of those who live in the Midwest and 32 percent of those in the South say traffic congestion is a serious problem. In the East, over one-third (37 percent) say traffic congestion is a serious problem. Compare this to the West where over half (56 percent) believe traffic congestion is a serious problem. http://www.harrisinteractive.com/harris_poll/index.asp?PID=732

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HNTB/GA DOT 2007	Georgia Department of Transportation Statewide Truck Lanes Needs Identification Study – Technical Memo #2: Forecasting and Analysis	2007	HNTB, with Cambridge Systematics and GeoStats LP for Georgia DOT	Uses statewide travel demand model and extensive truck travel data to estimate the benefits of a statewide system of truck-only lanes, either in place of or in addition to planned capacity expansion of the State's interstate system. http://www.gatrucklanestudy.com/
Hoback 2008	Sensitivity Analysis of Light Rail Transit Unit Capital Costs	2008	Hoback, A. (University of Detroit Mercy)	Looks at 24 recent light rail construction projects and applies sensitivity analysis to estimate unit costs of various types of construction. http://www.google.com/url?sa=t&ct=res&cd=2&url=http%3A%2F%2Feng-sci.udmercy.edu%2Fprograms%2Feng%2Fcivil-environmental%2Fresearch%2Ftransit-research%2F08-0024.pdf&ei=csJqSKXOMYSo8QSrkrCwDA&usg=AFQjCNG7Rh6oRkZkvrbgi3jUjDxgwtsSqQ&sig2=n0ZStLyojQpof23YHPa0Bw
Holguín-Veras 2007	Necessary Conditions for Offhour Deliveries and the Effectiveness of Urban Freight Road Pricing and Alternative Financial Policies in Competitive Markets	2007	Holguín-Veras, J. (Rensselaer Polytechnic Institute)	Paper suggests that Freight Road Pricing (FRP) alone will not be effective in diverting freight traffic to offpeak-periods, unless coupled with receiver incentives. This is due to the competitive nature of the delivery industry, wherein toll costs are rarely passed on to receivers, and even when they, are insignificant compared to the receiver's cost to start taking after-hour deliveries. The authors recommend FRP in conjunction with receiver incentives, and a particular focus on "large traffic generators."
Holguín-Veras et al 2005	The impacts of time-of-day pricing on the behavior of freight carriers in a congested urban area: Implications to road pricing	2005	Holguín-Veras, J., et al (Rensselaer Polytechnic Institute)	Paper examines the impacts of Port Authority of New York and New Jersey peak-period pricing scheme at six bridges and tunnels on freight patterns.
Hummer 2004	Handbook of Transportation Engineering – Ch. 14	2004	Hummer, J. (Kutz, Myer, ed.)	Chapter 14 – Intersection and Interchange Design. Compares different intersection and interchanges design types based on relative flow rates, safety, and land consumption. Makes specific recommendations for certain design elements based on predicted traffic flow rates.
ICF 2006	Congestion Management Process Innovations: A Menu of Options	2006	ICF for New York State MPOs	Offers information to MPOs to consider in implementing a Congestion Management Process (CMP). Provides information on innovative approaches to CMP activities. Topics include performance measures, monitoring, strategy evaluation, documentation, and linkages with other processes.
ICF/EPA 2002	Commuter Choice Benefits Calculator User Documentation	2002	ICF for U.S. Environmental Protection Agency	Estimates trip reduction from transit incentives and other worksite-based measures using COMMUTER Model.

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ICF/FHWA 2002	Economic Effects of Transportation: The Freight Story	2002	ICF and HLB for FHWA	Describes the linkages between freight transportation and the economy. Based on a review of 170 studies. http://www.icfi.com/publications/doc_files/fhwa%20freight%20story.pdf
IDAS Database	IDAS Benefits Database		Cambridge Systematics for FHWA	Inventory of information on the benefits of ITS strategies, used in developing the IDAS model. http://idas.camsys.com/
IIHS 2001	Status Report, July 28, 2001	2001	Insurance Institute for Highway Safety	Results of IIHS study looking at safety and delay reduction benefits of modern roundabouts. http://www.iihs.org/research/topics/roundabouts.html
IIHS 2005	Continuous Reliance on Traffic Signals: The Cost of Missed Opportunities to Improve Traffic Flow and Safety at Urban Intersections	2005	Bergh, C; R. Retting and E. Myers (Insurance Institute for Highway Safety)	Estimates delay and fuel consumption reductions resulting from replacing signalized intersections with roundabouts. http://www.iihs.org/research/paper_pdfs/mf_1848.pdf
ITE 1998	A Toolbox for Alleviating Traffic Congestion and Enhancing Mobility	1998	Institute of Transportation Engineers	Summary of traffic congestion management strategies and impacts. http://www.nhbs.com/a_toolbox_for_alleviating_traffic_congestion_and_enhancing_tefno_78708.html
ITE 2005	Benefits of Retiming Traffic Signals TENC 101-02: A Reference for Practitioners and Decision-makers About the Benefits of Traffic Signal Retiming –an ITE Informational Report	2005	Institute of Transportation Engineers	Presentation summarizing larger report on benefits of traffic signal improvements; includes descriptions of travel-time and delay savings for U.S. case studies. http://www.ite.org/meetcon/2005AM/Harris_Tues.pdf
ITS 1997	Ramp Up The Volume	1997	ITS International, November 1997	This article details how MnDOT uses a new generation of control algorithms called an Integrated Corridor Traffic Management-Ramp Metering System (ICTM-RMS), with the old freeway management system (FMS) as a fallback.
ITS Benefits Database	ITS Benefits Database		U.S. Department of Transportation	This on-line database provides information on the benefits of ITS strategies. http://www.benefitcost.its.dot.gov/its/benecost.nsf/BenefitsHome
Kirby 2007	Managing Congestion Through Innovative Pricing and Financing	2007	Kirby, R. F. (ITE Journal, July 2007)	Review of pricing strategies, from March 2007 ITE Technical Conference and Exhibit. Includes discussion of implementation issues.

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Kittleson 2005	Comparative Analysis of Signal Control	2005	Myers et al. (Kittleson and Associates)	PowerPoint presentation on roundabouts versus signalized intersection. Contains two charts showing reductions in vehicle delay in seven case study areas near Washington, D.C. www.ite.org/meetcon/2005AM/Rodegerdts_Wed.pdf
LAMTA 1999	Economic Impacts of the Long-Range Transportation Plan	1999	Cambridge Systematics and Economic Development Research Group for Los Angeles Metropolitan Transportation Authority	Uses REMI to analyze the economic benefits to Los Angeles County of three alternative regional plan scenarios compared to the no-build scenario.
LaPlante 2007	Strategies for Addressing Congestion	2007	LaPlante, J. N. (ITE Journal, July 2007)	Brief review of strategies for addressing congestion, from March 2007 ITE Technical Conference and Exhibit.
LCC 2007	London Congestion Charging Scheme: Fifth Annual Impacts Monitoring Report	2007	Transport for London	The Fifth Annual Impacts Monitoring Report draws on the most recent data for 2006, reflecting four years of operation of the scheme. http://www.tfl.gov.uk/assets/downloads/ fifth-annual-impacts-monitoring-report-2007-07-07.pdf
Lee and Kim 2006	Automated Work Zone Information System (AWIS) on Urban Freeway Rehabilitation: California Implementation	2006	Lee, E. and C. Kim	A microscopic simulation approach was used to evaluate the effects of an Automated Workzone Information System (AWIS) deployed near Los Angeles, California on Interstate 5 between Magic Mountain Parkway and Rye Canyon Road. The AWIS included vehicle detectors and three portable Dynamic Message Signs.
Litman 2007	Transit Price Elasticities and Cross-Elasticities	2007	Litman, T. (Victoria Transport Policy Institute)	Looks at the effects of various factors on transit ridership. These include fare and service levels and are disaggregated by trip type, transit mode, etc. http://www.vtpi.org/tranelas.pdf
Liu and Garber 2007	Identifying the Impact of Truck-Lane Restriction Strategies on Traffic Flow and Safety Using Simulation	2007	Liu, Q. and N. Garber	Simulation used to determine the impacts of truck-lane restrictions on safety and average speed, as influenced by factors such as truck percentage, roadway grade, number of lanes, density of interchanges, etc. http://cts.virginia.edu/docs/UVACTS-14-5-103.pdf
Meyer 2007	Combating Congestion through Leadership, Innovation, and Resources: A Summary Report on the 2007 National Congestion Summits	2007	Meyer, M. for AASHTO	Summarizes the findings of regional workshops held in AASHTO's four regional affiliates from June-August 2007 to discuss congestion management practices at state DOTs. Includes some examples of specific strategies and coordinated efforts. http://www.transportation.org/sites/ssom/docs/ CongestionSummitSUmmaryFINAL%20092107.pdf

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Mitretek 1999	ITS Impacts Assessment for Seattle MMDI Evaluation: Modeling Methodology and Results	1999	Wunderlich, Karl et al. (Mitretek) for FHWA	This study examined the impacts of integrated advanced traveler information services (ATIS), advanced traffic management systems (ATMS), and incident management systems (IMS) on a mixed freeway/arterial corridor in north downtown Seattle. http://www.itsdocs.fhwa.dot.gov/JPODOCS/REPTS_TE/11323.pdf
Mitretek-PB/NCHRP 2008	Incorporating ITS into the Transportation Planning Process: An Integrated Planning Framework (ITS, M&O, Infrastructure) Executive Guidebook	2008	Mitretek Systems and PB Consult for NCHRP (Web-Only Document 118)	Explores factors that are pushing regions and states towards integration of ITS in the transportation planning process, including the institutional, organizational, and technical processes that are included within it. In addition, this report examines challenges, transition strategies, and resources available to help agencies interested in adopting the integrated framework concept. http://onlinepubs.trb.org/onlinepubs/nchrp/nchrp_w118part1.pdf
MNDOT 2001	Twin Cities Metro Area Ramp Meter Study	2001	Cambridge Systematics for Minnesota DOT	In 2001, the Minnesota Department of Transportation conducted a study on ramp metering in the Twin Cities metro area. This study evaluated the traffic flow and safety impacts associated with turning off all 430 ramp meters for six weeks. http://www.dot.state.mn.us/rampmeterstudy/pdf/finalreport/finalreport.pdf
MNDOT 2006	Minnesota Mileage-Based User Fee Demonstration Project: Pay-As-You-Drive Experimental Findings	2006	Cambridge Systematics for Minnesota DOT	Final evaluation of MnDOT's demonstration project to simulate effects on vehicle use from conversion of fixed costs to variable per-mile costs. Findings from an experimental field test that measured participants' travel behavior under per mile priced and nonpriced conditions also are included. http://www.lrrb.org/PDF/200639A.pdf
NCHRP 457	Evaluating Intersection Improvements: An Engineering Study Guide	2001	Bonneson, J.A. and M. Fontaine (Texas Transportation Institute) for NCHRP (Report 457)	Establishes minimum thresholds and conditions under which different traffic control signals and intersection types are warranted. http://onlinepubs.trb.org/onlinepubs/nchrp/esg/esg.pdf
NCHRP 463	The Economic Implications of Congestion	2001	Cambridge Systematics, Regional Economic Models, Inc., and Economic Development Research Group for NCHRP (Report 463)	Details the cost of congestion to local and regional economies. The analysis goes beyond accounting for user expense and travel-time costs and includes additional productivity costs associated with travel-time variability, worker time availability, freight inventory, and logistics/scheduling, just-in-time production processes, and economies of market access. The study also demonstrates how congestion shrinks business market areas and reduces (or eliminates) the "agglomeration economies" of operating in large urban areas. http://onlinepubs.trb.org/onlinepubs/nchrp/nchrp_rpt_463-a.pdf

Short Citation	Title	Date	Author/ Source	Brief Description and Web Link
NCHRP 497	Financing and Improving Land Access to U.S. Intermodal Cargo Hubs	2003	Shafran, I. and A. Strauss-Weider for NCHRP (Report 497)	Case studies of 10 intermodal ports with land access issues and how those issues were resolved (or proposed solutions), including financial considerations.
NCHRP 572	Roundabouts in the United States	2007	Rodegerts, L. et al for NCHRP (Report 572)	Focuses mostly on safety benefits (but covers some congestion management issues) of converting traditional intersections to roundabouts. Stresses that roundabouts work best in low-volume areas. http://onlinepubs.trb.org/onlinepubs/nchrp/nchrp_rpt_572.pdf
NCHRP Synthesis 264	Modern Roundabout Practice in the United States	1998	Jacquemart, G. for NCHRP (Synthesis 264)	Survey of early implementers of "modern roundabouts," including key benefits, geometric and other design guidelines, and implementation issues. http://www.trb.org/publications/nchrp/nchrp_syn_264.pdf
NCTCOG 2006	Texas Metropolitan Mobility Plan: Breaking the Gridlock	2006	North Central Texas Council of Governments	The Texas Metropolitan Mobility Plan serves as a comprehensive, multimodal blueprint for transportation systems and services within the Dallas-Fort Worth Metropolitan Area. http://www.nctcog.org/trans/mtp/tmmp/TMMP_Report_2006_000.pdf
NCTCOG 2007	Pay-As-You-Drive (PAYD) Insurance Pilot Program: Phase 2 Midcourse Project Report	2007	Progressive County Mutual Insurance Company	The North Central Texas Council of Governments and Progressive Insurance Company, Inc. are testing the concept of a "Pay As You Drive" insurance program. This report summarizes the midterm or first phase results. A final report is expected in Jan 2008. http://www.nctcog.org/trans/air/programs/payd/MidTermResults.pdf
Niles 2008	JALA International: Home-based Telecommuting Cost-Benefit Analysis (web site)	2008	Niles, J.	Web site about telecommuting; includes a cost-benefit calculator. http://www.jalahq.com/
NJTA 2005	Evaluation Study of New Jersey Turnpike Authority's Time-of-Day Pricing Initiative	2005	Rutgers University for New Jersey Turnpike Authority	In September 2000, the New Jersey Turnpike Authority introduced EZPass technology along with the first stage of its time-of-day pricing program. In January 2003, toll levels for each time period and vehicle type were increased as part of the second stage of the NJ Turnpike time-of-day pricing program. http://www.cait.rutgers.edu/finalreports/FHWA-NJ-2005-012.pdf
NRDC 2007	Growing Cooler Update: Improving Transportation Choices	2007	Natural Resources Defense Council	Sketch-level assessment of potential nationwide VMT reductions from a variety of TDM strategies
NTOC 2007	National Traffic Signal Report Card	2007	National Traffic Operations Coalition	Survey of traffic operations practices throughout the U.S. http://www.ite.org/reportcard/technical_report%20final.pdf

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NYSDOT 2008	Report to the Traffic Congestion Mitigation Commission and Recommended Implementation Plan	2008	New York State DOT and Congestion Mitigation Commission	In 2007, New York created the Traffic Congestion Mitigation Commission, charged with developing a solution to the severe traffic congestion in New York City's central business district. The Commission recommended that the City and State implement congestion pricing in Manhattan. The congestion mitigation impacts of various proposals are discussed in this report, often described in percent VMT reduction. https://www.nysdot.gov/portal/page/portal/programs/repository/ TCMC-Final-Report.pdf
ODOT 2007	Oregon's Mileage Fee Concept and Road User Fee Pilot Program	2007	Oregon DOT	Final evaluation report of Oregon's 2007 experimental field test of the Mileage Fee Concept provides policy and institutional lessons learned and findings from experimental demand management. http://www.oregon.gov/ODOT/HWY/RUFPP/docs/RUFPP_finalreport.pdf
OECD 2007	Transport, Urban Form and Economic Growth: Conclusions of Round Table 137	2007	Organization for Economic Cooperation and Development	Discusses the productivity and growth effects of urban sprawl
PANYNJ 2005	Evaluation Study of Port Authority of New York and New Jersey's Time-of-Day Pricing Initiative	2005	Rensselaer Polytechnic Institute, Rutgers, et al for Port Authority of New York and New Jersey	On January 25, 2001, the PANYNJ approved a new pricing structure with tolls that varied according to time-of-day and payment technology. This report was prepared to monitor the impacts of the time-of-day pricing initiative, both at the systemwide level and at the user level. http://knowledge.fhwa.dot.gov/cops/hcx.nsf/All+Documents/ F28934FF571FF3C685256DB10063E81B/ $FILE/PANYNJ%20Final%20Report.pdf
Park and Chang 2000	Realizing Benefits of Adaptive Signal Control at an Isolated Intersection	2000	Park, B. and M. Chang	This paper discusses a simulation effort to estimate the benefit of adaptive signal control when compared to pretimed traffic signal timing plans. The study compared the performance of the two methods of signal control on a simplified, hypothetical intersection of two one-way roadways with single-lane approaches. The modeled adaptive signal control system uses a genetic algorithm-based signal optimization technique to determine the most appropriate signal timing plan for current traffic conditions.
Parsons and TTI 1997	Estimation of Benefits of Houston TranStar	1997	Parsons Transportation Group and Texas Transportation Institute	The Houston TranStar is responsible for the planning, design, operations, and maintenance of transportation operations and emergency management operations within the Greater Houston Area. http://www.houstontranstar.org/ [not a link to the paper]

Short Citation	Title	Date	Author/ Source	Brief Description and Web Link
PB 2005	Truck Only Toll Facilities: Potential for Implementation in the Atlanta Region	2005	PB for Georgia State Road and Tollway Authority	This study examined the feasibility of introducing truck only toll (TOT) lanes in the Atlanta road network as a means of improving the reliability and mobility of freight and passenger movement within and through the Atlanta region. In order to perform a broad feasibility analysis, this study examined three TOT lane alternative concepts (scenarios). Measures of the long-term performance of each scenario were developed to determine if any fatal flaws exist in the TOT concept. http://www.georgiatolls.com/PDFs/TOT_Final_Report_July2005.pdf
PB/NCHRP 2007	Future Options for the National System of Interstate and Defense Highways	2007	Parsons Brinckerhoff, et al for NCHRP (Project 20-24, Task 52)	Among other things, this report forecasts future travel demand on the Interstate system, potential expansion and operational improvements, and implications for congestion. http://onlinepubs.trb.org/onlinepubs/trbnet/acl/ NCHRP_20-24_52Task10_NCHRPFinal.pdf
PBQD 1993	The Pedestrian Environment	1993	Parsons Brinckerhoff Quade Douglas for 100 Friends of Oregon	Compares VMT and trip rates based on pedestrian environment factor.
PBQD/Alameda Co. 2005	HOT Credit Lanes Feasibility Study	2005	Prepared by Parsons Brinckerhoff Quade and Douglas, Inc, et al, for the Alameda County Congestion Management Agency	The study analyzed key aspects of the FAIR lanes concept, including toll revenues, impact on vehicle volumes and speeds, travel forecasting, freeway operations, and public perceptions. The economic and performance impacts of 14 alternative policy scenarios were analyzed in terms of revenue generated and traffic measures, such as vehicle speeds and volumes. http://knowledge.fhwa.dot.gov/cops/hcx.nsf/All+Documents/ 4067E2FECD8228E9852570660056B26B/ $FILE/hot_credit_lanes_feasibility_study_final.pdf
Perrin et al. 2004	Advanced Transportation Management System Elemental Cost Benefit Assessment	2004	Perrin, J. et al. (University of Utah)	This report provides assessments of the impact on transportation operations and a cost-benefit analysis of four Advanced Traffic Management System components deployed in the Salt Lake Valley of Utah: incident management teams, ramp metering, signal coordination, and variable message signs. The cost analysis is based on regional value-of-time metrics.

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PierPass 2007	Press Release: "PierPass Offpeak Program: Diverts Five Million Trucks from LA Daytime Traffic"	2007	PierPass	2007 Press Release describing Offpeak program has diverted more than five million truck trips from peak daytime traffic since the program's start in July 2005. The program has eliminated costly bottlenecks at the Ports of Los Angeles and Long Beach, reduced gridlock on area freeways and curtailed air pollution from idling traffic. In an average week, Offpeak removes 60,000 truck trips from the freeways during busy commuting hours, reducing congestion and benefiting local air quality. http://www.pierpass.org/files/offpeak_information/5_million_trucks_final_5_7_07.pdf
PNYC 2006	Growth of Gridlock: The Economic Case for Traffic Relief and Transit Improvement for a Greater New York	2006	Partnership for New York City	Looking at just a limited set of costs and industry sectors and using very conservative assumptions, economists assisting the Partnership in the preparation of this report were able to identify more than $13 billion in annual costs to businesses and consumers, billions in lost economic output and tens of thousands of lost jobs that result from severely overcrowded conditions on the region's streets and highways. http://www.pfnyc.org/publications/Growth%20or%20Gridlock.pdf
Poole 2007	Miami Toll Truckway: Preliminary Feasibility Study	2007	Poole, R. Jr., Reason Foundation	Preliminary study of four alternative alignments of truck-only tollways from Port of Miami to MIA and rail/distribution facilities northwest of the airport. Documents cost feasibility as well as congestion benefits to the region. http://www.reason.org/ps365_miami_truckways.pdf
Prud'homme and Kopp 2006	The Stockholm Toll: An Economic Evaluation	2006	Prud'homme, R. and P. Kopp	Economic evaluation of the welfare impacts of congestion pricing in Stockholm
PSRC 2006	Puget Sound Traffic Choices Study	2006	Puget Sound Regional Council	Preliminary presentation of results of Puget Sound Traffic Choices Study of mileage-based user fees in 2006. Contains detailed analysis of road user choice and behavior under a broadly implemented and sustained tolling treatment. http://wstc.wa.gov/AgendasMinutes/agendas/2006/ Nov14/Nov14_BP2_PSRC_TrafChoicesStudy.pdf
Public Roads 2004	Red Light, Green Light	2004	Halkias, J. and M. Schauer (Public Roads Journal)	Uses Oakland, MI and Syracuse, NY as case studies for signal timing/control optimization strategies. http://www.tfhrc.gov/pubrds/04nov/07.htm

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Reason 2006	Building Roads to Reduce Traffic Congestion in America's Cities: How Much and at What Cost?	2006	Reason Foundation	This report quantifies the magnitude of traffic congestion and the cost of its removal through the provision of additional capacity. With the help of 32 participating urbanized areas, the report uses sophisticated traffic modeling techniques to determine how much additional capacity will be needed to relieve severe congestion. These findings are then extended to all 403 urbanized areas. The report then estimates the cost of providing that additional capacity. http://www.reason.org/ps346.pdf
RITA 2008	ITS/Operations Guide 2008	2008	U.S. DOT	A "meta reference" – A comprehensive listing of over 500 documents, videos, web sites, training courses, software tools, and points of contact related to ITS and other innovative transportation strategies. http://www.resourceguide.its.dot.gov/default.asp
Romero and Stolz 2002	Cost Estimating for Underground Transit: Too Dangerous to "Guesstimate"	2002	Romero, V. and J. Stolz (Jacobs Associates)	Brief paper describing why it is quite difficult and inaccurate to use unit costs to estimate the cost of constructing underground transit facilities. http://www.jacobssf.com/too_dangeroustoguestimate.html
RSG 1999	Tappan Zee Congestion Relief Study Final Report	1999	Resource Systems Group, Inc, Wilbur Smith, et al	This report summarizes the findings of a comprehensive evaluation of traveler and employer reactions to congestion pricing concepts for the Tappan Zee Bridge between Westchester and Rockland Counties in New York. http://www.tzbsite.com/tzb-library/research/seismic-study-pdf/study-199908.pdf
RTA 2006	Moving Beyond Congestion: Vision and Strategy	2006	Regional Transportation Authority (Chicago, IL)	Draft for public comment of Illinois Regional Transportation Authority's long-term congestion management and public transit investment plan. Pegs congestion savings of RTA transit system at $1.8 billion a year in the Chicago-metro area and a projected cost of $2.3 billion in congestion of a no-investment scenario in the future. http://movingbeyondcongestion.org/vision-and-strategy.html
SAIC 2004	Intelligent Transportation Systems in Work Zones: A Case Study – Dynamic Lane Merge System	2004	Scriba, T, and T. Luttrell (SAIC for FHWA)	In the summer 2002 and 2003, the Michigan DOT rebuilt a 13.5-mile section of I-94 in the suburbs of Detroit. To help smooth traffic flow, the DOT deployed a dynamic lane merge (DLM) system. The system was designed to regulate merging movements in transition areas where lane configurations changed from three lanes to two lanes. http://www.itsdocs.fhwa.dot.gov//JPODOCS/REPTS_TE/14011.htm

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SANDAG 2001	I-15 Congestion Pricing Project, Monitoring and Evaluation Services: Phase III Year Three Overall Report	2001	San Diego State University for the San Diego Association of Governments	Summarizes the findings from the evaluation of the Interstate 15 (I-15) Congestion Pricing Project. The project was a three-year demonstration that allowed single occupant vehicles to use the existing I-15 high-occupancy vehicle lanes, known as the I-15 Express Lanes, for a fee. http://fastrak.sandag.org/pdfs/yr3_overall.pdf
SCAG 2005	Goods Movement in Southern California: The Challenge, The Opportunity, and The Solution	2005	Southern California Association of Governments	Models congestion benefits and regional economic impacts of truck-lane network in Southern California. http://www.scag.ca.gov/goodsmove/pdf/GoodsmovePaper0905.pdf
SCCRTC 2002	Route 1 Congestion Management Study	2002	Santa Cruz County Regional Transportation Commission	Project Study Report-Project Development Support to explore alternatives to reduce congestion on Route 1 between State Park Drive and Morrissey Avenue. The alternatives include: widening for HOV; widening for mixed flow vehicles; widening for HOT; interchange/ramp improvements; auxiliary lanes at various locations; ramp metering (with all build alternatives). The study analyzed traffic impacts to 2020, with three measures of congestion reported (delay, speed, time). http://www.dot.ca.gov/dist05/projects/ scrhwy1cms/scrhwy1cms_psr_overview.pdf
Schiffer et al 2006	Comparative Evaluations on the Elasticity of Travel Demand	2006	Schiffer, R.G., M. W. Steinvorth, R. T. Milam	Uses Wasatch Front model to test induced demand; also includes literature review of induced demand studies.
SCRITS	Screening Analysis Spreadsheet for ITS		Federal Highway Administration	Spreadsheet analysis tool to estimate ITS benefits. Contains estimates of benefits of various strategies. http://www.fhwa.dot.gov/STEAM/scrits.htm
SHE 1999	Adverse Weather Traffic Signal Timing	1999	Short Elliott Hendrickson, Inc. for Minnesota DOT	A study performed for the Minnesota Department of Transportation assessed the feasibility of implementing weather-related traffic signal timing for a coordinated traffic signal system. The study corridor included Trunk Highway 36 between McKnight Road and Hadley Avenue in the Minneapolis-St. Paul metropolitan area. http://trafficware.infopop.cc/downloads/00005.pdf
Shladover et al 2004	Assessment of the Applicability of Cooperative Vehicle-Highway Automation Systems to Bus Rapid Transit and Intermodal Freight: Case Study Feasibility Analyses in the Metropolitan Chicago Region	2004	Shladover, S. et al, (Partners for Advanced Transit and Highways, University of California at Berkeley)	Presents benefit-cost analysis of implementing CVHAS technologies, such as automatic steering control, automatic platooning, or fully automated driving, to BRT facilities or truck-only intermodal connector road in the Chicago region. http://repositories.cdlib.org/its/path/reports/UCB-ITS-PRR-2004-26/

Short Citation	Title	Date	Author/ Source	Brief Description and Web Link
Skabardonis 2001	ITS Benefits: The Case of Traffic Signal Control Systems	2001	Skabardonis, A.	This paper summarizes an evaluation of the benefits of optimizing traffic signal timing plans, coordinating traffic signal control, and implementing adaptive signal control at locations throughout the State of California.
Smallen 1998	Intermodal Connectors: NHS Catches up to the 1990s	1998	Smallen, D. for Public Roads Magazine (May 1998)	Brief discussion of the role and scale of intermodal connectors in the National Highway System. http://www.tfhrc.gov/pubrds/may98/nhs.htm
SPC 2005	2005 Congestion Management Process of the Southwestern Pennsylvania Commission	2005	Southwestern Pennsylvania Commission	This document represents a strategy for managing congestion on designated corridors throughout the region. Twenty-five strategies have been evaluated for suitability on each corridor on the CMP monitoring network. Two strategies stood out: public relations and education for transportation supportive development and traffic signal improvements. http://www.spcregion.org/trans_cong_arch_reports.shtml
SRF 1997	Portable Traffic Management System Smart Work Zone Application: Operational Test Evaluation Report	1997	SRF Consulting Group for Minnesota DOT	The Minnesota Department of Transportation used Portable Traffic Management Systems (PTMS) to minimize traffic delays and improve safety at work zones on I-94 between Minneapolis and St. Paul, Minnesota and on I-35 located south of the Twin Cities. The equipment at each site consisted of trailer mounted dynamic message signs (DMS), and multiple PTMS units equipped with mast mounted DMS, and digital surveillance cameras. http://dot.state.mn.us/guidestar/pdf/workzone.pdf
SRTA 2005	High-Occupancy Toll Lanes and Truck Only Toll Facilities: Potential for Implementation in the Atlanta Region	2005	Georgia State Road and Tollway Authority	The regionwide performance of the transportation system with HOV, HOT, and TOT network strategies provide greater network efficiency versus a HOV strategy alone. Three scenarios were modeled based on regional networks and traffic levels in 2030. All three scenarios resulted in a similar level of vehicle miles traveled, while vehicle hours traveled decreased slightly (1 percent) with HOT lanes and more significantly (5 percent) with TOT lanes. HOT scenario highways carry approximately 1 percent more trips and TOT scenario highways carry approximately 2 percent more trips than highways under the HOV scenario. The TOT scenario resulted in 15 percent fewer congested lane-miles on roadways adjacent to the TOT lanes during the afternoon (p.m.) peak.
Sunkari 2004	The Benefits of Retiming Traffic Signals	2004	Sunkari, S., in ITE Journal	Journal article that uses multiple U.S. and Canadian cities as case studies for signal timing/control optimization strategies.

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Sussman et al. 2000	What Have We Learned About ITS?	2000	Sussman, J. et al. (Massachusetts Institute of Technology)	This paper explores mobility benefits realized from U.S. deployments of adaptive signal control systems in Los Angeles, California; Broward County, Florida; Newark, Delaware; Oakland County, Michigan; and Minneapolis, Minnesota.
TAC 2006	Quantification of Congestion – Calculating Benefits	2006	iTrans Consulting and the Regional Municipality of York, Ontario	Value of time and benefit-cost analysis were used to evaluate 11 different congestion relief strategies at an intersection in York, Ontario
TCRP 107	Analyzing the Effectiveness of Commuter Benefits Programs	2006	ICF and Center for Urban Transportation Research	Chapter 3, based on research from metropolitan areas across the United States, examines the effects of transit benefits programs on employee travel behavior and on transit agency ridership, revenues, and costs. Based on survey data from 25 regions plus trip reduction datasets from Arizona, Southern California, and Washington State. www4.trb.org/trb/onlinepubs.nsf
TCRP 1998	The Costs of Sprawl – Revisited	1998	Burchell, B., et al for Transit Cooperative Research Program (Report 39)	Summarizes past studies on the various impacts of sprawl.
TCRP 2000	The Costs of Sprawl – 2000	2000	Burchell, B., et al for Transit Cooperative Research Program (Report 74)	Estimates the national costs and other impacts of sprawl. http://onlinepubs.trb.org/Onlinepubs/tcrp/tcrp_rpt_74-a.pdf
TCRP 35	Economic Impacts of Transit	1999	Cambridge Systematics, et al for TCRP (Report 35)	Presents methods to value the economic impact of transit investments, and examples of their application.
TCRP 78	Estimating the Benefits and Costs of Public Transit Projects: A Guidebook for Practitioners	2002	ECONorthwest and Parsons Brinckerhoff Quade and Douglas for TCRP (Report 78)	Direct capital (rolling stock only) and operating costs are examined as part of a guidebook on benefit-cost analysis of transit investments. http://onlinepubs.trb.org/onlinepubs/tcrp/tcrp78/guidebook/tcrp78.pdf
TCRP 95 c12	Traveler Response to Transportation System Changes, Chapter 12: Transit Pricing and Fares	2004	McCollom, B., and Pratt, R., et al. for TCRP (Report 95, Chapter 12)	Describes elasticities and traveler responses to various types and magnitudes of transit fare changes, including peak/offpeak fare structures. http://trb.org/news/blurb_detail.asp?id=4132

Short Citation	Title	Date	Author/ Source	Brief Description and Web Link
TCRP 95 c14	Traveler Response to Transportation System Changes, Chapter 14: Value Pricing	2003	Pratt, R., et al. for TCRP (Report 95, Chapter 14)	Summarizes case studies, results, impacts, etc. of major value pricing projects internationally and domestically. http://onlinepubs.trb.org/onlinepubs/tcrp/tcrp_rpt_95c14.pdf
TCRP 95 c9	Traveler Response to Transportation System Changes, Chapter 9: Transit Scheduling and Frequency	2004	Evans, J., et al for TCRP (Report 95, Chapter 9)	Case studies examining the relationship between service frequency changes and transit ridership. http://onlinepubs.trb.org/onlinepubs/tcrp/tcrp_rpt_95c9.pdf
TCRP B-4	Cost-Effectiveness of TDM Strategies	1994	COMSIS for Transit Cooperative Research Program, Project B-4	Evaluates some 50 employer-based TDM programs in the United States and estimates that the average reduction in vehicle trips.
TRB 2002	The Congestion Mitigation and Air Quality Improvement Program: Assessing 10 Years of Experience	2002	Transportation Research Board (Special Report 264)	Comprehensive review of the CMAQ program. Contains an assessment of effectiveness and costs a variety of congestion mitigation strategies. http://www.nap.edu/catalog.php?record_id=10350
TRB 2003	Access Management Manual	2003	Transportation Research Board	Comprehensive review of access management, including operational benefits.
TRB 242	Peak-Period Fees To Relieve Traffic Congestion, Volume 1: Committee for Study on Urban Transportation Congestion Pricing	1994	Transportation Research Board (Special Report 242)	Summary report includes a variety of possible impacts and case studies of pricing in metro areas.
TRB 340	Convertible Roadways and Lanes: A Synthesis of Highway Practice	2004	Transportation Research Board	Reviews several case studies of convertible-lane practices, including usage of road shoulders, on-street parking lanes, contraflow lanes, etc. http://onlinepubs.trb.org/onlinepubs/nchrp/nchrp_syn_340.pdf
TTI 1999	Evaluation of Changeable Lane Assignments for Daily Operations	1999	Texas Transportation Institute	Evaluates the effectiveness of the changeable lane assignment system (CLAS) as a space management tool to optimize daily operations in a primary corridor. The benefits of using CLAS for recurring demand management were mixed. Improvements in lane balance in some cases were often tempered by increased lane delays. Although some reductions in delay and queuing were found, statistically significant reductions in approach delay and queuing were not indicated for the three studied locations. http://tti.tamu.edu/documents/2910-1.pdf

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TTI 2002	Do Bottleneck Improvements Really Reduce Congestion?	2002	Texas Transportation Institute	Brief description of TTI's data collection on bottleneck improvement benefits, and four specific Texas cases. http://tti.tamu.edu/publications/researcher/ newsletter.htm?vol=38&issue=2&article=7&year=2002
TTI 2007	2007 TTI Urban Mobility Report	2007	Texas Transportation Institute	In 2007, congestion caused urban Americans to travel 4.2 billion hours more and to purchase an extra 2.9 billion gallons of fuel for a congestion cost of $78 billion (Exhibit 1). This was an increase of 220 million hours, 140 million gallons, and $5 billion from 2004. The benefits from operational treatments and public transportation likewise appear to decline compared to the 2005 report; the actual numbers increase if the same methods are used. http://tti.tamu.edu/documents/mobility_report_2007_wappx.pdf
U of MD	Applied Technology and Traffic Reduction Analysis Program (ATTAP)		University of Maryland-Engineering	ATTAP is jointly initiated by the Office of Traffic and Safety at the Maryland State Highway Administration and the Traffic Safety and Operations Laboratory at the University of Maryland – College Park. The primary focus of the program is to develop and apply advanced technologies in contending with day-to-day congestion and in improving traffic safety in highway networks. http://attap.umd.edu/ UAID_ags.php?UAIDType=11&Submit=Submit&iFeature=6
U.S. DOT	National Strategy to Reduce Congestion (Web Site)		U.S. Department of Transportation	In 2006, the U.S. DOT identified congestion relief as a top priority and launched its National Strategy to Reduce Congestion. The effort includes seven components: Urban Partnership Agreements, Public–Private Partnerships, Corridors of the Future, Reducing Southern California Freight Congestion, Reducing Border Congestion, Increasing aviation capacity, and Operations and Technology Improvements. http://www.fightgridlocknow.gov/
U.S. DOT 2006	National Strategy to Reduce Congestion on America's Transportation Network	2006	U.S. Department of Transportation	This white paper calls for the consideration of new, nontraditional solutions to the problem of congestion. This paper outlines a broad course of action for urban surface transportation operations that aligns with the six-point action plan identified by U.S. DOT. Fifteen page primer on congestion statistics and arguments. http://isddc.dot.gov/OLPFiles/OST/012988.pdf

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U.S. DOT 2007a	Freight Facts and Figures	2007	U.S. Department of Transportation	All kinds of facts and figures on freight movement in the U.S. Includes some projections. http://www.ops.fhwa.dot.gov/freight/freight_analysis/nat_freight_stats/docs/07factsfigures/pdf/fff2007.pdf
U.S. DOT 2007b	Intelligent Transportation Systems for Traffic Signal Control	2007	U.S. Department of Transportation	Contains examples of benefits of traffic signal coordination, adaptive control from projects around the U.S.
U.S. DOT 2007c	ITS Unit Costs Database	2007	U.S. DOT	Presents unit costs for a wide range of ITS equipment and services. http://www.its.dot.gov/tech_assistance.htm
U.S. DOT ITS JPO 2003	Washington State – British Columbia International Mobility and Trade Corridor (IMTC) ITS – CVO Border Crossing Deployment Evaluation Draft Final Report	2003	SAIC for U.S. DOT ITS Joint Program Office	Evaluation of benefits and costs of ITS deployment and dedicated ITS truck lanes at Blaine, Washington border crossing facility. http://www.itsdocs.fhwa.dot.gov/JPODOCS/REPTS_TE/13952.html
ULI 2007	Growing Cooler: The Evidence on Urban Development and Climate Change	2007	Ewing, R., et al for Urban Land Institute	This report provides an estimate of the carbon dioxide reductions that could be expected nationwide through land use changes for compact or "smart growth" development.
USCBP 2007	Free and Secure Trade (FAST) Fact Sheet	2007	U.S. Customs and Border Protection	Overview of the FAST program. http://www.cbp.gov/xp/cgov/trade/cargo_security/ctpat/fast/
USCOC 2008	Transportation: A Brake on the Nation's Economic Growth and Competitiveness?	2008	Cambridge Systematics with Boston Logistics Group and Alan Pisarski for U.S. Chamber of Commerce	This report examines the relationship between transportation investment and long-term economic productivity, competitiveness, and growth.
Varaiya 2007	Effectiveness of California's High-Occupancy Vehicle (HOV) System	2007	Varaiya, P. for Partners for Advanced Transit and Highways, University of California at Berkely	Evaluation of HOV lanes in California. http://www.path.berkeley.edu/path/publications/pdf/prr/2007/prr-2007-05.pdf
Volpe 2000	Incorporating ITS Solutions Into the Metropolitan Transportation Planning Process: Overcoming Institutional Barriers	2000	Volpe National Transportation Systems Center for FHWA	Four areas selected for in-depth case studies of successful approaches for integrating ITS into the metro planning process: Chicago, Dallas-Fort Worth, Los Angeles, and Miami. Albany and Dallas also are discussed. http://www.plan4operations.dot.gov/docs/overcoming.pdf

Short Citation	Title	Date	Author/ Source	Brief Description and Web Link
Wendelboe 2003	Traffic Management Applications on the Køge Bugt Motorway, Denmark	2003	Wendelboe, J. T. (European Commission Directorate on General Energy and Transport)	This report examines a temporary traffic management system implemented in association with a work zone in Copenhagen, Denmark. Dynamic message signs and traffic detectors were deployed on freeways surrounding the work zone to support dynamic route information at diversion points and the implementation of variable speed limits.
Winston-Langer 2006	The Effect of Government Highway Spending on Road Users' Congestion Costs	2006, May	Winston, C. and A. Langer, in Journal of Urban Economics, vol. 60	Estimates costs of congestion of $2.46 billion to truckers and $7.58 billion to firms, for a total cost of congestion of about $10 billion (in 2,000 dollars). This compares with $37.5 billion in total congestion costs, meaning the freight sector incurs 27 percent of congestion costs. http://www.brookings.edu/views/papers/winston/200605-aeijc.pdf
Winston-Shirley 2004	The Impact of Congestion on Shippers' Inventory Costs	2004	Winston, C. and Shirley, C. for FHWA	Report present estimates of the costs of congestion to shippers using three different methodologies. Econometric models and FHWA's freight datasets are modeled to present national cost of congestion estimates ranging from $3 billion to $7 billion. http://www.fhwa.dot.gov/policy/otps/060320d/060320d.pdf
WSA 2005	Best Practices in Parking Management	2005	Wilbur Smith Associates	Part of the Master Parking Plan for downtown Los Angeles. References drop in single-vehicle trips in Portland on page 30. www.wilbursmith.com/westernwsa/cra-la/documents/Best%20Practices.pdf
WSAUD 2007	Performance Audit Report: Washington State Department of Transportation: Managing and Reducing Congestion in Puget Sound	2007	Washington State Auditor's Office	The audit addressed the nine elements in Initiative 900 and the objectives outlined in the legislation to examine: 1) The effectiveness of the Department of Transportation's current highway investments and infrastructure usage given current and projected highway user volume over the next five years and 2) The financial and nonfinancial costs of any recommended improvements over the next five years. http://www.sao.wa.gov/reports/auditreports/auditreportfiles/ar1000006.pdf
WSDOT 2001	SR-520 Eastbound Morning Ramp Metering Three-Month Study	2001	Washington State Department of Transportation	This report is an examination of the implementation of morning metering operation at two onramps on SR-250 in Washington. Four weeks of data from both before and after the inception of morning ramp metering were collected and used to determine average weekday figures. http://www.wsdot.wa.gov/NR/rdonlyres/ 9FB40ACE-EE17-4B20-BED5-633D38AC8A7B/0/520eb3monthstudy.pdf

Short Citation	Title	Date	Author/ Source	Brief Description and Web Link
WSDOT 2005	Highway Construction Costs: Are WSDOT's highway construction costs in line with national experience?	2005	WSDOT	Reviews construction costs for 36 highway projects in Washington State and around the country. http://www.wsdot.wa.gov/biz/construction/CostIndex/CostIndexPdf/HighwayConstructionCosts2005.pdf
WSDOT 2006	2006 Congestion Relief Analysis Report – Phase One	2006	Washington State Department of Transportation	In 2006 WSDOT completed a congestion relief analysis of three major urban areas: Central Puget Sound, Spokane and Vancouver. Computer models analyzed a variety of congestion management strategies (general purpose lanes, carpool lanes, transit, transportation system efficiency improvements, and travel demand management, particularly roadway value pricing) The results provided some answers about how effective these strategies (singly and in combination) could be in reducing travel delay in 2025. http://www.wsdot.wa.gov/planning/Studies/UrbanCongestionRelief/2006report.htm
WSTC 2006	Travel Behavior, Emissions, and Land Use Correlation Analysis in the Central Puget Sound	2006	Frank, L., M. Bradley, and K. Lawton Associates for Washington State Transportation Commission	Uses tour-based models to examine how measures of land use mix, density, and street connectivity where people live and work influences their trip making patterns, including trip chaining and mode choice. http://www.wsdot.wa.gov/research/reports/fullreports/625.1.pdf