

## TRAFFIC FLOW MANAGEMENT

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Americans living in the fifty most congested cities spend an average of thirty-three hours each year stuck in traffic. Congestion causes much more than driver aggravation: air quality suffers, vehicle idling and stop-and-go traffic reduce fuel economy by as much as 30 percent, and we lose billions of dollars in productivity. These are the consequences as the automobile does what it is designed to do—transport a highly mobile population. Continued suburban expansion, reduction in household size, increase in number of workers per household, and general changes in lifestyle have all contributed to increased travel demand and greater congestion.

Even without congestion, from the perspective of capital utilization and energy consumption, automobile and roadway use is inefficient. First, the majority of personal transportation energy is consumed in moving personal vehicles that contain only one occupant and drive one or two hours a day. Second, the transportation infrastructure usually operates below capacity. States expend tremendous resources building highways to accommodate peak period demands (7 A.M. to 9 A.M. and 3 P.M. to 6 P.M.). Most of these lanes are not needed for the rest of the day. Rush hour

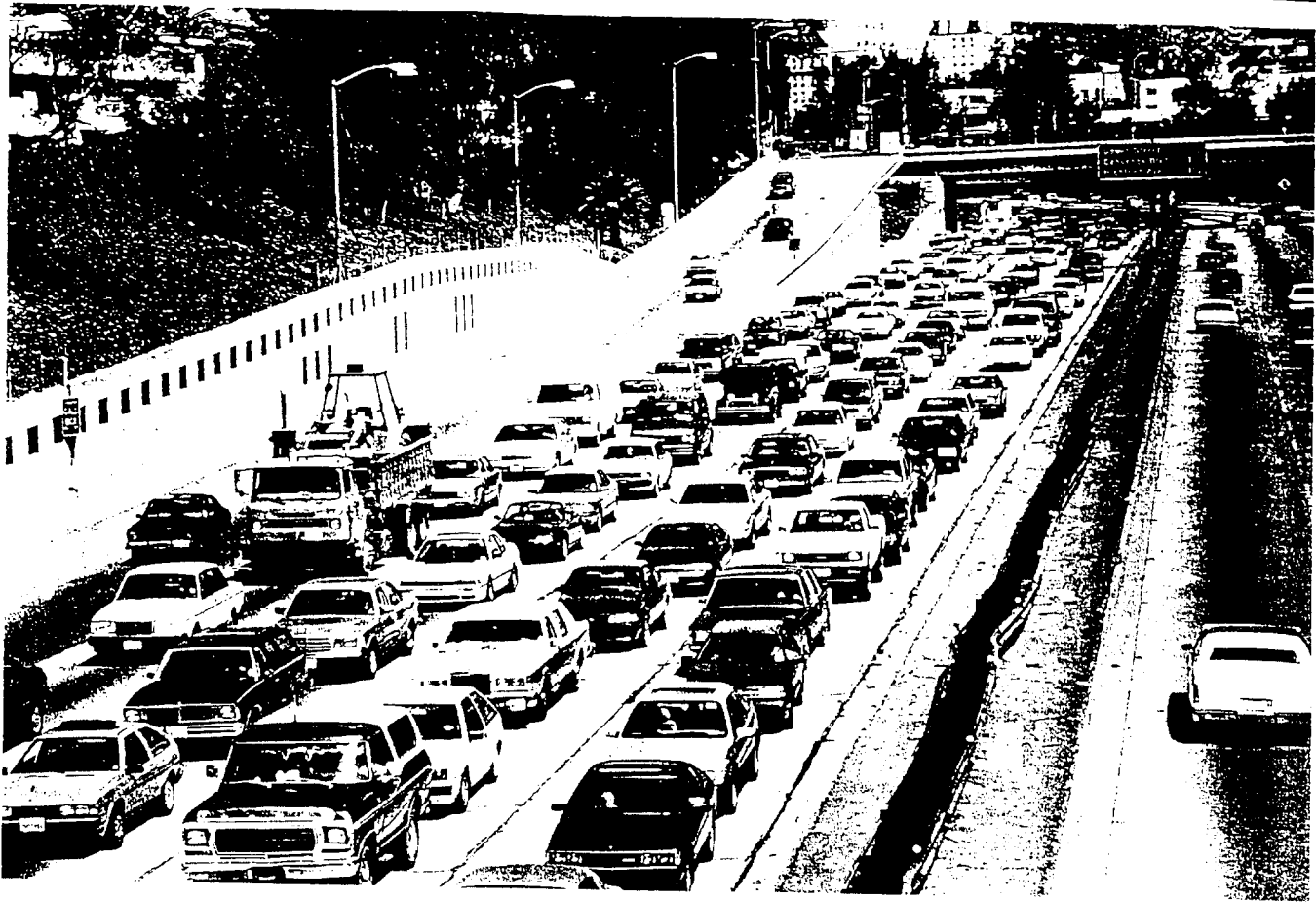
demand still exceeds capacity in many places, resulting in disruption of traffic flow, stop-and-go driving conditions, a drop in freeway throughput, increased fuel consumption, increased vehicle emissions, and wasted time. Nevertheless, the personal vehicle remains the preferred means of transportation in much of the world given the personal freedom and economic opportunity (access to jobs) that it affords.

Using capital and energy more efficiently is a common goal of government, business, and the individual. State agencies have responded to congestion delay by building more capacity and/or increasing the efficiency of existing capacity. At the local level, however, there is growing opposition to the detrimental noise, air quality, and space infringements of building more and bigger highways. Federal environmental and transportation regulations have shifted from capacity expansion to a focus on congestion reduction and air quality improvement. Because mobility enhances regional economic development and productivity, shifting travel demand out of the peak period, or efficiently improving transportation supply (without necessarily adding new major facilities) still provides tremendous public benefits. Recent strategies have focused on behavior modification (transportation demand management strategies) and targeted improvements to the transportation infrastructure (transportation supply improvement strategies).

### TRANSPORTATION DEMAND MANAGEMENT STRATEGIES

The objective of demand management strategies is to encourage or require drivers to reduce the frequency and length of automobile trips, to share rides, or to use alternative modes of transportation. When peak period automobile trips are shifted out of the peak, or into alternative transportation (such as carpools, mass transit, bicycling, or walking) congestion declines and the remaining automobile users benefit from improved travel times. Demand management measures include no-drive days, employer-based trip reduction programs, parking management, park and ride programs, alternative work schedules, transit fare subsidies, and public awareness programs. Demand management measures may or may not require intensive capital investment, but are usually characterized by ongoing operating costs.

Researchers have been able to identify strategies (and specific incentives and disincentives) that can



Cars in a traffic jam on the Hollywood Freeway in California. (Corbis Corporation)

change travel behavior at individual facilities. Effective strategies can be tailored for individual businesses and activities as a function of employment classification, land use, and transit service availability. The fact that many strategies are effective at reducing travel demand at individual facilities is not controversial. But it is difficult to implement regional demand management programs that are acceptable to the public without micromanagement by the government. Such regional demand reduction strategies are typically implemented in the form of regulatory mandates, economic incentives, and education campaigns.

#### Regulatory Mandates and Employer-Based Trip Reduction

Businesses, operating in a market economy, have little incentive to implement demand management strategies on their own. They pay for the costs of shipment delays associated with moving goods and services to the marketplace (these costs are incorporated into the selling price of the goods and services).

However, the vast majority of society's congestion cost is external to marketplace price-setting. Companies sometimes implement measures to reduce employee travel to their facility when there's insufficient parking. Normally, they provide convenient automobile access because it makes it easier to attract and keep employees.

Regulatory mandates require, either directly or indirectly, that specific segments of the population change their trip-making behavior. Examples of direct regulatory mandates include: automobile bans in downtown areas, restrictions on motor vehicle idling time (i.e., heavy-duty vehicles), restricted access to airport terminals for certain types of vehicles, odd/even day gasoline rationing at retail filling stations (based on license plate numbers), restricted hours for goods delivery in urban areas, and peak hour restrictions on truck usage in downtown areas. Direct mandates have proven extremely unpopular. Although developing and rapidly growing industrial countries (e.g., Singapore, Mexico, and China) do

implement such measures, none are implemented on a sustained and widespread basis in the United States.

Implementation of indirect regulatory mandates has been more common than direct mandates, primarily in the form of trip reduction ordinances implemented by local governments. These ordinances require employers to increase the average vehicle occupancy of employee vehicles during commute periods, but usually allow employers great flexibility in developing their strategies.

During the late 1980s and early 1990s, employers implemented trip reduction measures in many urban areas. Regulatory agencies developed commute vehicle occupancy goals that would result in fewer vehicle trips to the facility during the morning peak. Employers could offer their employees incentives (e.g., cash rebates for carpool participants) or impose disincentives (e.g., parking fees for employees who drove alone) to achieve these ridership goals.

The largest and most prominent experience with trip reduction ordinances in the United States was Regulation XV, adopted December 11, 1987, in the South Coast (Los Angeles) area. The regulation required employers of a hundred or more individuals to prepare and implement trip reduction plans between the home and worksite. Employers developed their own incentive programs to encourage workers to rideshare or use alternative transportation. Facilities reported progress annually, and they adjusted their plans each year until they achieved their ridership goal.

The tripmaking aspects of specific measures implemented by employers under Regulation XV were widely variable. Trip reductions depended on such local factors as employer size and location, employment and site characteristics, location of labor pool, and socioeconomic composition. A 1991 study of seventy-six facilities in the Regulation XV program found no apparent correlation between the number of incentives offered and the improvement in ridership levels. The quality, not the quantity of incentives offered was the driving force for behavioral change. Two factors had a significant effect on ridesharing: (1) use of parking incentives and disincentives coupled with transit pass or commute subsidies; and (2) management commitment coupled with the presence of an on-site transportation coordinator. A program to guarantee rides home for emergencies and last minute work/personal schedule changes was necessary but insufficient condition to encourage ridesharing.

Over the entire Los Angeles region, employer-based demand management strategies were slow to evolve. Employers were required only to develop "approvable" plans to achieve specified ridership goals with no penalty for failure to achieve the goals. A detailed study of 1,110 work sites found that the implementation of Regulation XV reduced vehicle use to participating facilities by about 5 percent during the first year of the program. The most instructive finding of this study is that the primary improvements in ridership came from increased use of carpools. All other changes were trivial: a slight increase in vanpools and compressed workweeks, a slight decrease in bicycling/walking and telecommuting, and no change in transit use. This finding suggested that reduced vehicle use can be achieved with little or no institutional change, because carpools do not require the same level of organizational effort and financial support as many other options.

Even if successfully implemented, the overall travel implications of programs similar to Regulation XV would be modest. Commute trips represent about 25 percent of daily trips, and commute trips to facilities with a hundred or more employees represent approximately 40 percent of commute trips in the Los Angeles area. Even if commute trips to affected facilities are reduced between 5 percent and 20 percent, employer-based trip-reduction strategies may yield total daily trip reductions of between 0.5 percent and 2 percent (although primarily achieved during peak periods). The costs of such initiatives are substantial. Employers often hire rideshare coordinators and provide incentives, and regulators must monitor and enforce the program. In a survey of more than 400 Los Angeles area facilities the typical cost of placing employees in carpools or transit through personalized ridesharing assistance ranged from \$7.72 per employee in large firms (~10,000+ employees) to \$33.91 per employee in small firms (~100 employees).

A few years after Regulation XV was implemented, when medium-sized businesses (100–250 employees) came under the regulatory requirements, the business community began exerting significantly increased political pressure on the South Coast Air Quality Management District (SCAQMD) to repeal the regulation, and took their case directly to Congress. On December 23, 1995, Congress amended Section 182(d)(1)(b) of the Clean Air Act. The new language allowed air quality planning agencies to opt out of the required employer-based programs.

Overnight, employee commute programs around the nation became voluntary, disappearing entirely from air quality management plans.

The SCAQMD undertook an eighteen-month study in which the agency encouraged voluntary rideshare efforts for medium-sized facilities. However, the exemption of facilities from employer-based trip reduction and ineffective implementation of voluntary programs yielded an increase in pollutant emissions. Despite the failure of voluntary measures, the California State Legislature permanently exempted medium-sized businesses from the Los Angeles regulations. The largest air pollution control agency with the worst air quality in the nation could not retain their commute program for medium-sized employers over public objection.

#### Public Information and Education

Recent behavioral shifts, such as the overall decrease in the number of smokers and the increase in residential recycling activity, suggest that ongoing media campaigns coupled with formal education programs can effectively influence human behavior. Many of California's local air pollution control districts have implemented education programs as a means of increasing public awareness of how travel behavior affects air quality. The California Air Resources Board prepared a variety of information packets for government decision-makers as well as the public. Numerous states and local air pollution control agencies have followed suit across the United States.

Education campaigns implemented in conjunction with regulatory mandates can make employer-based trip reduction strategies more efficient at both the facility and regional levels. The SCAQMD implemented an education program to support their employer trip reduction program. District staff members advised corporate representatives on cost-effective strategies implemented by other companies in the region. They recommended compressed work weeks, in-house rideshare matching, subsidized transit passes, carpool/vanpool subsidies, preferential carpool parking, flexible hours, telecommuting, bicycle lockers and showers, and company award/prize programs. Agency staff also recommended guaranteed ride home programs as a necessary supplement to successful carpooling strategies. Of the sixty-five employers that received advice and provided final cost information, about 88 percent (fifty-seven) reported a significant decrease in program imple-

mentation costs as a direct result of switching to the new options recommended by SCAQMD in 1997. The average annual cost per worksite declined from \$35,616 to \$16,043 (an average of \$19,573 per worksite, or \$70 per employee).

Programs aimed at the younger generation through grade school may achieve positive results over time. Children's programs are likely to yield a future generation that is educated about the economic, environmental, and social costs associated with transportation. Given the historic failures of regional travel programs and public resistance of pricing strategies, public awareness campaigns are becoming a major focus of U.S. regulatory agencies. It remains to be seen if these investments will prove cost-effective.

#### Economic Incentives

Economic incentives in transportation include monetary incentives or disincentives to the transportation consumer (i.e., vehicle operator or passenger) as encouragement to change travel behavior. Economists have long argued that monetary signals serve as the most economically efficient method to achieve changes in transportation demand. They argue that consumers will consume goods and services most efficiently when they are required to pay the full cost of the goods and services. Provided costs are not set too high, economic incentives should achieve behavioral change more efficiently than prescriptive rules. Economic incentives including congestion pricing and gasoline tax increases have received strong support from businesses, environmentalists, and local press editorials in San Francisco.

Transportation economics literature argues persuasively for the implementation of congestion pricing to improve the efficiency of the current transportation system. Area licensing schemes are also an option, where vehicle owners purchase stickers allowing the car to enter the most congested areas of the city during peak hours. Singapore, Hong Kong, and Oslo and Bergen in Norway provide examples of area license schemes.

The Environmental Defense Fund and Regional Institute of Southern California sponsored comprehensive modeling studies of pricing on transportation behavior for the Los Angeles area. The findings are as follows:

- Regional congestion pricing of \$0.15 per mile may yield a vehicle miles traveled (VMT) reduction of about 5.0 percent and trip reduction of 3.8 percent;

- Regional \$3.00 per day parking charges may yield a VMT reduction of about 1.5 percent and a trip reduction of 1.8 percent;
- Regional \$0.60 per hour nonemployee parking charges may yield a VMT reduction of about 3.5 percent and trip reduction of 4.3 percent;
- Mileage and smog-based registration fees averaging \$110 per vehicle per year may yield a VMT reduction of about 0.4 percent and trip reduction of 0.7 percent.

Because of academic interest in congestion pricing theory, Congress established the Congestion Pricing Pilot Program in the Intermodal Surface Transportation Efficiency Act (ISTEA) of 1991 to fund congestion pricing studies and demonstration programs. Due to a lack of political support for congestion pricing on public roads, no significant congestion pricing programs have been implemented in the United States.

High occupancy toll (HOT) lanes are proving to be a potentially viable alternative to congestion pricing. HOT lanes allow single occupant vehicles to access new high occupancy vehicle lanes or facilities by paying a toll. HOT lane facilities are now operating in San Diego, California; Riverside, California; and Houston, Texas. Because the public perceives HOT lanes as providing new capacity and appears more accepting of tolls on these facilities, additional investigation into the consumer acceptance and economic benefits of HOT lanes will continue.

*Gasoline Taxes.* Studies in 1994 indicated that a \$2.00 increase per gallon in gasoline tax (raising United States prices from about \$1.00 to about \$3.00 per gallon) could yield a VMT reduction of about 8.1 percent and trip reduction of 7.6 percent. Determining the long-term effects of higher gasoline prices can be difficult. Fuel costs are a small component of the total cost of owning and operating an automobile. Research indicates that gasoline demand is relatively inelastic over the short-term and somewhat more elastic over the long-term. Significant increases in fuel price can affect short-term automobile use. However, when fuel prices rise significantly, demand for new fuel-efficient vehicles also increases. Individuals who purchase more fuel efficient vehicles can retain many of the trips and VMT without experiencing significant increases in total operating cost. Fuel price, VMT demand, and fuel intensity are interlinked, and the cumulative effect yields the change in net travel demand and net fuel consumption.

*Parking Pricing.* In the United States, paying for parking is the exception rather than the rule; 90 to 95 percent of auto commuters pay nothing for parking. Nationwide, employers provide 85 million free parking spaces to commuters, with a fair market value of nearly \$36 billion a year. Even in the central business district of Los Angeles, where parking fees are more common than in most areas, of the 172,000 office workers, more than 54,000 drivers park at their employer's expense.

Despite the fact that most employees pay nothing for parking, it is important to remember that there is no such thing as free parking. Even if employers do not pay an outside vendor and instead provide their own lots for employee parking, these lots must be constructed, gated, monitored, and maintained. Companies providing parking to employees at no charge pay an opportunity cost for not putting their property to more productive uses. The land could be developed and used in producing more company income or could be sold for development by others. Employers simply pass on the real and opportunity costs of parking to the consumers of the goods and services provided by the company. These consumers benefit little, if at all, from the parking provided to employees. Failure to charge employees for parking constitutes an inefficient pricing structure.

Travelers are highly sensitive to parking charges because the charges represent a large change in their out-of-pocket costs. Parking costs is one of the three most frequently cited factors (along with convenience and time saved) in the carpool decision. This responsiveness to parking prices is economically rational because motorists treat the vehicle purchase and annual insurance payments as sunk costs with respect to daily travel decisions, leaving parking costs as a large percentage of out-of-pocket expenses. For instance, typical commute trips to the Los Angeles core business district cost less than \$2.00 per day in gasoline costs. Adding the fair market value of parking to gasoline costs can increase out-of-pocket expenses to roughly \$6.00 per day. Studies show that free parking is a greater incentive to driving alone than providing free gasoline.

Various case studies lend support to the finding that parking prices are significant in affecting trip-generation and mode choice. An early study of employer-paid parking effects on mode choice, conducted in the late 1960s in the central business district of Los Angeles, examined county workers receiving employ-

er-paid parking and federal employees paying for their own parking. The CARB (1987) study found that only 40 percent of the employees subject to parking fees drove to work alone, while 72 percent of similar employees that were not subject to parking fees drove alone. The availability of transit and alternative modes, and the amount of available free parking, influence the effectiveness of parking pricing. An analysis of thirteen employers in 1991 found that when they instituted paid parking programs the number of trips at the worksite was reduced by 20 percent. Other studies in the Los Angeles area indicate that between 19 percent and 81 percent fewer employees drive to work alone when they are required to pay for their own parking.

Employer-paid parking is changing in California because of a law requiring employers to "cash out" free parking. The 1992 California law, and subsequent regulations, require employers who provide free or subsidized offsite parking to their employees to provide a cash equivalent to those employees who do not use the subsidized parking (California Health and Safety Code 43845). The program applies to employers of more than fifty persons in areas that do not meet the state ambient air quality standards (between 3 percent and 13% of the medium and large employers in the Los Angeles area).

The California Air Resources Board (CARB) sponsored research in 1997 to evaluate eight case studies of firms that complied with California's parking cash-out. The number of drive-alone trips to these facilities dropped 17 percent after cashing out. The number of carpool participants increased by 64 percent; the number of transit riders increased by 50 percent; the number of workers arriving on foot or bicycle increased by 39 percent; and total commute trip vehicle miles of travel dropped by 12 percent. These findings are a revelation because this significant shift in travel behavior resulted from a regional policy.

Most businesses in Los Angeles have hesitated to implement employee parking pricing, despite the fact that increased parking fees can increase vehicle occupancy much more efficiently than other strategies. Most employees who receive free parking view this subsidy as a right, or fringe benefit of employment.

### TRANSPORTATION SUPPLY IMPROVEMENT STRATEGIES

Transportation supply improvement strategies change the physical infrastructure or operating char-

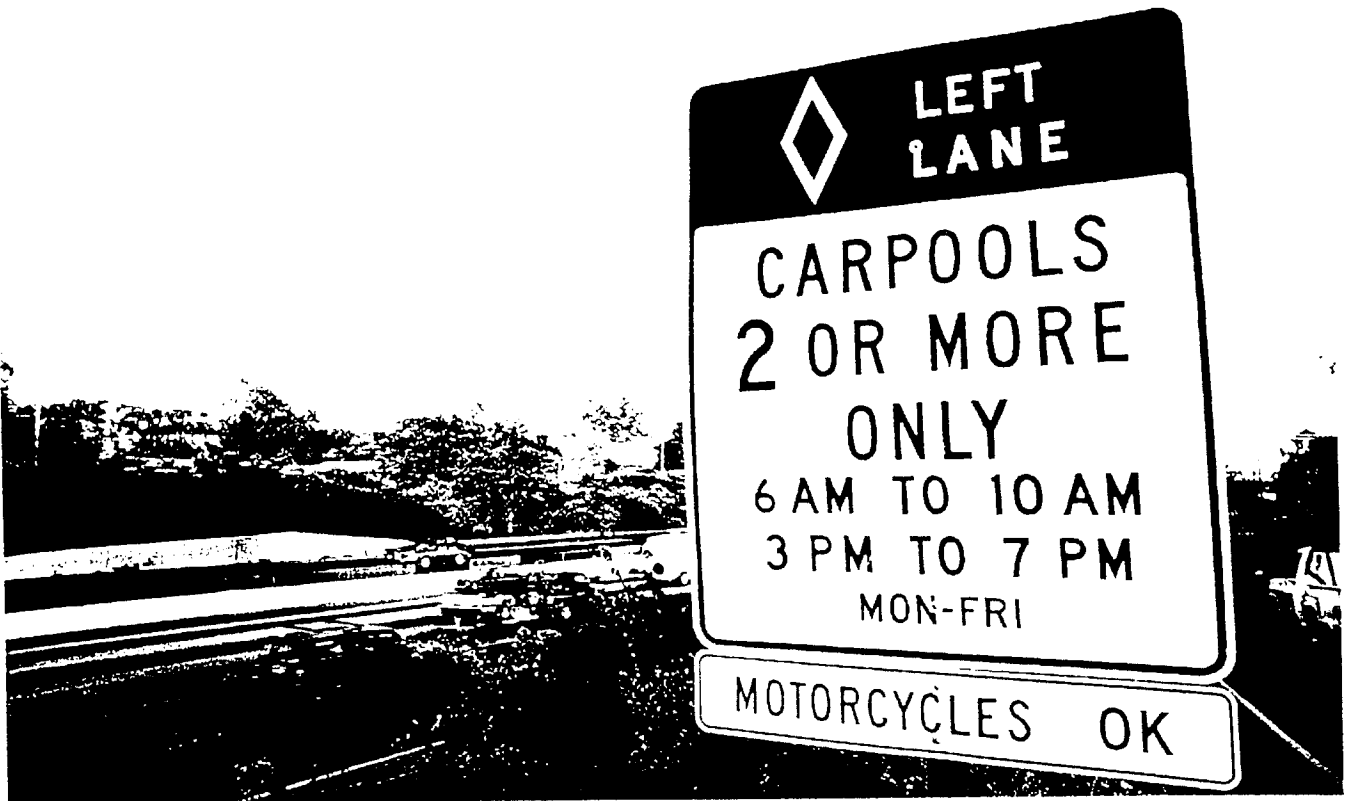
acteristics to improve traffic flow and decrease stop and go movements. They often require intensive capital investment and comprise bottleneck relief, capacity expansion, and construction improvements. Regional transportation plans usually include integrating high-occupancy vehicle (HOV) systems (differentiated from construction of HOV lanes). Many areas are also refocusing efforts on traditional technology-oriented means that reduce traffic congestion: signal timing optimization, rapid incident response, ramp metering, and applications of intelligent transportation system technology.

#### HOV Systems

Serious congestion delay often exists in the same urbanized areas that fail to meet federal air quality standards. In these areas, capacity expansion projects are usually difficult to implement. The emissions from the increased travel demand that follows corridor expansion can create additional air quality problems. One effective means of expanding capacity while restricting a corridor's travel demand and emissions growth is the addition of HOV lanes. Only carpools and transit vehicles can use these HOV lanes. The efficiency of carpool lanes as a system improvement is a function of the characteristics of the overall HOV system. Vehicles need to remain in free-flowing HOV lanes until they reach the exit for their destination or the time benefits associated with the carpooling activity are limited. Forcing carpools out of dedicated lanes, into congested lanes, and back into dedicated lanes is an impediment to carpool formation. HOV systems that ensure faster travel through congested regions are more successful in attracting users. Many urban areas are integrating HOV bypass facilities, and HOV onramps/offramps into interconnected systems.

#### Signal-Timing Optimization

Traffic signal-timing improvement is the most widespread congestion management practice in the United States. During the late 1970s and early 1980s, many cities and municipalities began focusing on improving signal timing as a means to reduce fuel consumption. Traffic engineers program traffic signal green, yellow, and red times at a local traffic control box located at the intersection. Signal-timing improvements can range from a simple change of a timing plan (such as increasing green time on one leg of an intersection during a peak period), to complex computer-controlled signal coordination along an



Carpool lanes, like this one on a California freeway near the Westwood neighborhood in Los Angeles, were designed to encourage more people per car. (Corbis-Bettmann)

entire transportation corridor. By linking control boxes at consecutive intersections and coordinating the green lights along a traffic corridor, vehicles moving in platoons can pass through consecutive intersections without stopping. In general, signal-timing programs reduce the number of stops, reduce hours of stop delay, and increase overall system efficiency. Consumers benefit from reduced congestion, increased safety, reduced stress, and improved response times for emergency vehicles.

Transportation engineers model signal-timing improvements using simulation programs and system optimization routines. In optimization programming, timing plans will be changed to purposely delay some vehicles, or platoons of vehicles, whenever such a delay has the potential of reducing congestion delay for many other vehicles on the road.

Numerous studies agree that signal-timing optimization programs are cost-effective. In 1986 California had an average first-year fuel use reduction of 8.6 percent from signal-timing programs. In 1980

the Federal Highway Administration's National Signal Timing Optimization Project examined the effectiveness of signal-timing improvements in eleven U.S. cities. The study found that these cities had reduced vehicle delay by more than 15,500 vehicle hours per year, stops per intersection by more than 455,000 per year, and fuel consumption by more than 10,500 gallons per year. Signal-timing optimization also has the potential to significantly decrease vehicle emissions in urban areas. Many cities do not place signal-timing improvement near the top of their annual resource priority list for transportation funding. Future programs that employ real-time signal controls (traffic responsive control strategies) will become widespread once program resources are made available by states and municipalities for the necessary technology and expertise to implement these systems.

#### Rapid Incident Response Programs

Roadside assistance programs detect and rapidly respond to crashes and breakdowns to clear the vehicles from the roadway as quickly as possible. Crashes

often result in lane blockages that reduce capacity until the crash is completely removed from the system. Even a vehicle stalled on the shoulder of the road can create significant delays. After the incident is cleared, additional time is required for the congestion to clear. Reducing the duration of lane blockages by even a few minutes each can save thousands of hours of total congestion delay each year.

Many urban areas are now using video detection systems to monitor traffic flow. The systems, such as Autoscope, detect changes in video pixels to estimate traffic flow and vehicle speeds on freeways and major arterials. Significant differences in average speeds from one monitor to another indicate the presence of an accident between video monitoring locations. With early detection of an incident, rapid accident response teams (either roving the system or staged in specific locations along the system) can be dispatched immediately. Cellular telephones will also play an increasing role in incident detection programs as the cellular network density increases.

A recent study of the Penn-Lincoln Parkway indicated that the annual program investment of \$220,000.00 for their roadside assistance program reduces congestion delay by more than 547,000 hours per year (and a benefit-cost ratio of 30:1).

### Ramp Metering

Major urban areas in the United States have begun implementing ramp metering to optimize performance of major freeway systems. A ramp meter brings vehicles on the onramps entering the freeway to a complete stop during peak periods and releases vehicles to the freeway one or two at a time. Metering prevents queues of vehicles from entering the traffic stream and disrupting freeway traffic flow. Ramp meters delay the onset of congested stop-and-go activity, allowing freeways to continue to operate at efficient flow rates for extended periods. Ramp metering delays vehicles arriving at the ramps, but the net congestion savings on the freeway more than offsets the ramp delay. Although emissions are significantly lower on the freeway systems when metering maintains smooth traffic flow, the net emissions benefits of such systems are not clear at this time. The hard accelerations associated with vehicles leaving the stop bar on the ramp result in significantly elevated emissions levels. New ramp metering research projects are trying to determine the system-wide tradeoffs in emissions.

### Intelligent Transportation Systems

A variety of intelligent transportation systems (ITS) with the potential to improve traffic flow and relieve congestion are currently being explored. ITS technologies range from simple delivery of traffic information into the vehicle (helping drivers optimize route choice decisions) to complete vehicle automation. Although many of the proposed ITS strategies require development of new roadway and electronic infrastructure systems, some new technologies will evolve over the near term. Drivers can expect to access, via cellular Internet connections, detailed transportation system performance data. Electronic in-vehicle maps and systems data will allow users to optimize travel decisions and avoid getting lost. New radar systems will transmit warnings from roadside systems to vehicles, giving construction zones a new level of protection. Onboard collision avoidance systems may also prevent a significant number of rear-end crashes that cause congestion.

### RELATIVE EFFECTIVENESS OF DEMAND AND SUPPLY STRATEGIES

Due to political changes regarding transportation control measures (TCMs), the CARB shifted from advocating TCMs in the late 1980s to evaluating their cost effectiveness by the mid 1990s. In 1995 they studied the cost effectiveness of twenty emissions reduction strategies funded by California vehicle registration fees. The CARB analyses indicate that signal timing, purchases of new alternative fuel vehicles, and construction of bicycle facilities can be cost effective compared to many new stationary source control measures. A videophone probation interview system designed to substitute for office trips resulted in an agency cost savings, indicating that there are still technology projects that can simultaneously attain emissions reductions and save public dollars. Of the twenty measures, eleven tried to change travel demand, and nine tried to improve traffic flow or to shift drivers to new vehicles or alternative fuels. Only six of the eleven demand management measures proved cost-effective. The technology-oriented supply improvement strategies (such as signal timing) and fuel shifts fared better, with eight of the nine measures proving cost-effective.

### MODELING THE EMISSIONS IMPACTS OF TRAFFIC FLOW IMPROVEMENTS

Experts believe that current emissions models overestimate emissions at low operating speeds. They



predict emissions solely as a function of average speed. However, emissions are a strong function of speed/acceleration operating conditions. Modal emission rate models demonstrate that emissions in grams/second are fairly consistent when the vehicle is operating at low to moderate speed with low acceleration rates. Under these conditions, the gram/mile emissions rates are a function of the constant gram/mile rate and the amount of time the vehicle spends on the road segment in question (which is a function of average speed). Emissions can skyrocket under high-speed conditions and conditions of moderate speed with high acceleration and deceleration rates. The operating condition corresponding to the lowest emissions and reasonably efficient fuel consumption is smooth traffic flow, probably between 20 to 35 mph, with little acceleration and deceleration.

Evaluation of traffic flow improvement projects using the current emission rate modeling regime is bound to underestimate the air quality benefits. Because emissions are activity-specific, it is important to develop methods that can estimate the effect of traffic flow improvements on trip emissions in terms of changes in speed/acceleration profiles. The Georgia Institute of Technology and University of California at Riverside are currently developing emissions models that can assess the benefits of traffic flow improvements. The application of these modal emissions models is expected to show that improved signal timing may have a pronounced impact on improving emissions.

## CONCLUSION

Evidence suggests that demand management initiatives have had relatively small impacts on travel behavior and fuel consumption in the United States. Direct agency intervention at the regional level has not worked as intended. During the 1990s, economic incentives designed to internalize the personal and social costs of the automobile seemed to be the most logical and promising ways of achieving changes in travel behavior. As consumers internalize the true costs of owning and operating the personal automobile, individual tripmaking decisions become more rational, increasing system efficiency. Strategies such as congestion pricing, emission fees, and even pay-as-you drive automobile insurance received a great deal of attention in state legislatures and in the popular press. Before the public widely accepts pricing strategies in

the United States, regulators need to address a variety of equity dilemmas. In an era of cheap and abundant energy, it is likely that such pricing arguments will focus on potential air quality and congestion benefits rather than on energy consumption benefits.

The most successful transportation-related economic incentive to date has been the parking cash-out program in California. Limited-scale implementation has been very successful. Regional parking pricing is likely to be a viable travel demand strategy, but will be difficult to adopt. Tax codes that allow employers to provide parking as a tax-exempt employee benefit would need to change. Employers and employees need to feel that the costs of parking are real. By implementing pricing strategies that the public will support, and simultaneously continuing public education campaigns explaining the energy and environmental problems associated with owning and operating an automobile, gradual acceptance of more widespread incentives might be achieved.

Despite the implementation and performance limitations of demand management strategies, metropolitan areas have been able to significantly improve traffic flow by implementing of transportation system improvement strategies. Lane expansion projects that provide bottleneck relief have become the focus of new roadway construction. Traffic signal timing optimization, rapid incident response systems, and implementation of HOV systems and high-occupancy toll lanes have significantly enhanced system capacity and reduced congestion. These strategies are capital intensive, but the returns on investment in congestion relief and fuel and emissions savings have been significant. The public seems much more willing to expend resources to enhance capacity than to endure less personal mobility imposed by demand management strategies.

Because of continued increases in vehicle ownership, tripmaking, and mileage, many researchers question the extent to which system improvement projects can mitigate congestion growth. As congestion worsens in major urban areas, there will be a greater focus on demand management strategies. In addition, land use strategies are getting more attention. Transit trips typically account for only 3 percent of the total trips made in the United States. Only in cases where transit is available, where origin and destination land use characteristics match desired tripmaking characteristics, and where transit costs (transit time, wait time, fares, and opportunity) are lower than automobile

costs, do Americans opt to commute by transit. Proper design of land use, at densities that support transit operation and provide more opportunity to walk to common destinations, can provide significant long-term changes in travel patterns that minimize congestion, fuel consumption, and motor vehicle emissions. Because land use decisions come under local jurisdiction, federal agencies are now developing guidance documents for state and local agencies.

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See also: Air Pollution; Emission Control, Vehicle; Energy Management Control Systems; Government Intervention in Energy Markets.

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