Urban Freeway Gridlock Study: Decreasing the Effects of Large Trucks on Peak-Period Urban Freeway Congestion

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The Urban Freeway Gridlock Study investigated the effects of large trucks on peak-period urban freeway congestion. The study, undertaken for the California Department of Transportation at the direction of the California legislature, was prompted by concerns about freeway congestion and proposals to regulate large-truck traffic on the freeways. The study focused on the freeway systems in the Los Angeles, San Francisco, and San Diego metropolitan areas. It addressed the effects of large trucks, strategies to reduce congestion (improved traffic management, expanded incident management, mandatory night shipping and receiving, and mandatory peak-period truck bans), and the economic effects of these strategies. It was concluded that the volume of large trucks on the freeways does not have a significant effect on peak-period congestion but that truck-involved incidents and accidents do affect congestion significantly. Truck traffic makes a relatively small contribution to freeway congestion except on those few highly congested freeways where truck volumes exceed 10 percent of total vehicles. It was recommended that the state expand and improve its incident management programs and concurrently expand and intensify its long-term traffic management programs. The state should support a pilot program in Los Angeles to determine whether a cost-effective night shipping and receiving program can be developed. Areawide freeway truck bans should not be pursued; however, time-of-day and lane restrictions should be researched. Finally, it was recommended that the state collect data and improve traffic modeling procedures used to estimate the effects of trucks on air quality.

Portions of the U.S. urban freeway systems are saturated during the peak commute periods. The number of people who want to use the freeways is simply greater than the capacity of the freeways at those times of day, and the result is congestion. Congestion increases travel time, accident rates, and air pollution. These factors force people to travel earlier or later than they would like—a phenomenon called peak-spreading—or to forgo trips. In addition, they force businesses to pay more to move their goods. The problem is greatest in Los Angeles because freeway congestion also contributes substantially to air pollution, which imposes environmental and economic costs on the whole region, not just on commuters and motor carriers caught in freeway congestion.

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The seriousness of these problems and the degree of public concern are evident in recent proposals that deal with congestion-related issues. The most sweeping of these is the program announced in September 1988 by Los Angeles Mayor Thomas Bradley in which he proposed a multifaceted attack on the problems of freeway congestion and air pollution. The key elements of his plan were (a) a truck-permitting program that would drastically reduce the number of large trucks allowed to operate on the streets of the city of Los Angeles during the morning and evening peak periods, (b) regulations requiring large businesses to stay open longer in the evenings for shipping and receiving, (c) stronger truck safety enforcement, and (d) more rapid accident cleanup.

However, changing travel patterns is difficult and costly because people and businesses are dependent on freeway systems. Freeways serve both personal travel (for work, shopping, and recreation) and urban and Interstate goods movement. Americans have organized much of their lives and businesses around the mobility and access provided by the urban freeway systems: manufacturers depend on just-in-time delivery of components to their assembly lines to reduce inventory costs, retailers depend on overnight delivery of goods to restock shelves, and families depend on a steady flow of food to supermarkets to keep themselves fed.

At issue is how best to manage the freeways at peak periods to minimize congestion and how to do so equitably without major disruption to people's lives and their economy.

The Urban Freeway Gridlock Study was performed by Cambridge Systematics for the California Department of Transportation (Caltrans). It addressed three questions posed by the California legislature:

1. What are the impacts of large trucks on peak-period freeway congestion?
2. Can management techniques reduce congestion?
3. What are the economic costs of these techniques to commuters, motor carriers, business, industry, and the public?

SCOPE OF WORK

The study, which focused on the freeway systems in the Los Angeles, San Francisco, and San Diego metropolitan areas, dealt primarily with the impact of large trucks on these systems. For this study, a large truck was defined as having three or more axles and a gross vehicle weight rating of at least 26,000 lb.

The work was organized around the following five topics.

Current Conditions

Traffic flows at 40 freeway sites in the Los Angeles area, 25 sites in the San Francisco area, and 13 sites in the San Diego area were videotaped and analyzed to determine the number and types of large trucks on the freeways during peak periods. Next, public officials, industry associations, motor carriers, and shippers and receivers were interviewed to evaluate the impact of congestion on freeway and trucking operations. Finally, current research on truck accidents and the effects of trucks on traffic flow was reviewed.

Management Techniques

An extensive list of freeway and truck management techniques was assembled and screened. Four strategies were specified for detailed analysis: (a) traffic management, (b) incident management, (c) night shipping and receiving, and (d) peak-period truck bans.

Implementation Feasibility

California and federal statutes and regulations governing freeways and motor carriers were reviewed. In addition, leading court cases dealing with freeway and truck regulation were reviewed. Federal and state officials were surveyed to determine current experience in implementing and operating freeway and truck management programs.

Economic Impacts

Estimates of the number of truck movements by industry and type of motor carrier were developed to determine which industries generate the most truck traffic. Public agencies, carriers, shippers, and receivers were interviewed to estimate the direct economic effects of freeway and truck management strategies. The indirect economic effects of the strategies on the Los Angeles, San Francisco, San Diego, and California economies were estimated using a regional economic model.

CURRENT CONDITIONS

Large-Truck Travel Patterns

Large trucks account for three-fourths of all medium- and heavy-duty truck travel (excluding travel by pickup and panel trucks) in the Los Angeles, San Francisco, and San Diego areas. Large trucks also account for most of the truck travel on freeways. In Los Angeles it is estimated that large trucks account for 80 to 90 percent of all truck miles on the freeways. Most of these are heavy trucks, typically five-axle, 18-wheel tractor-semitrailers, and most are registered in California. Large-truck travel patterns in the Los Angeles, San Francisco, and San Diego areas are similar to those in other major urban areas except that California has a larger proportion of twin trailer trucks than most other states.

Proportion of Large Trucks in Freeway Traffic

In the Los Angeles and San Francisco areas, it was found that large trucks constitute 4.0 percent of all vehicles during the morning peak and 2.5 percent of all vehicles during the evening peak. The proportions are significantly lower in San Diego: 1.8 percent of all traffic during the morning peak and 0.8 percent during the evening peak. The percentage and absolute number of large trucks are highest during the midday period in all three areas. During that time, large trucks average 5.5 percent of all vehicles in Los Angeles and San Francisco and 2.5 percent of all vehicles in San Diego. These percentages are equivalent to 300 trucks per hour per direction in Los Angeles, 220 trucks per hour per direction in San Francisco, and 100 trucks per hour per direction in San Diego. The averages and observed ranges for each area are presented in Table 1.

Few freeways are highly congested and have a significant proportion (more than 10 percent) of large trucks in the traffic stream. In Los Angeles, such freeways include I-5, I-605, I-710, and SR-60; in San Francisco, I-80, I-880, and I-580.

TABLE 1 LARGE TRUCKS AS A PERCENTAGE OF TOTAL VEHICLES (ONE DIRECTION ONLY)

	Los Angeles	San Francisco	San Diego
A.M. peak (7:00–9:00 a.m.)			
Weighted average	3.8	4.2	1.8
Observed range	0.5–17.2	0.8–13.2	0.7–5.7
Midday offpeak (11:00 a.m. to 1:00 p.m.)			
Weighted average	5.5	5.4	2.5
Observed range	0.7–16.2	0.6–12.1	0.6–4.8
P.M. peak (4:00–6:00 a.m.)			
Weighted average	2.6	2.4	0.8
Observed range	0.2–13.2	0.3–6.8	0.1–1.9

NOTE: Averages are weighted by volume, all sites, and all time.

None of the freeways surveyed in San Diego has more than 6 percent large trucks in the traffic stream. At 60 percent of the survey sites, large trucks compose no more than 3 percent of all vehicles; at 90 percent of the sites, they compose no more than 9 percent of all vehicles.

As a general pattern, highly congested freeway segments tend to have lower truck volumes than do moderately congested freeway segments. An estimated 30 percent of freeway segments in Los Angeles, 20 percent in San Francisco, and 10 percent in San Diego are highly congested. These freeway segments have high traffic volumes, operate at levels of service E and F (stop-and-go traffic averaging less than 35 mph), and have a high rate of fatal and injury accidents per mile. Large-truck volumes on these highly congested segments average 3.5 percent, whereas large-truck volumes on moderately congested freeway segments average 4.2 percent.

Types of Trucks

Of the large trucks on the freeways during the peak periods, 65 percent are tractors hauling a single trailer, 20 percent are tractors hauling double trailers, 12 percent are single-unit straight trucks, and 3 percent are other configurations (such as tractors without trailers). By body type, 55 percent are vans, 25 percent are refrigerated vans, 10 percent are flatbeds, and the remaining 10 percent are predominantly tankers and construction equipment. These proportions are similar across all three metropolitan areas.

Industries Served by Trucks

The industries generating the most truck miles of travel in the Los Angeles area are wholesale trade (37 percent), durable goods manufacturing (28 percent), and nondurable goods manufacturing (19 percent). Together, these three industry groups generate almost 90 percent of all truck miles of travel in the Los Angeles area.

Private truck fleets owned by business and industry account for about half of all truck miles of travel; most of their trips are short-haul trips (less than 200 mi). Common carriers account for the other half of the truck miles of travel; about one-third of their trips are short haul and two-thirds are long haul (over 200 mi).

Effect of Trucks on Freeway Traffic Flow

Trucks affect traffic flow in their lane because they occupy more roadway space than passenger cars and cannot accelerate, decelerate, or maintain speed on upgrades as easily as passenger cars. The magnitude of their effect varies greatly with the type of truck, its weight, the volume of traffic on the freeway, and the roadway grade. On urban freeways where there are fewer than 10 percent trucks in the traffic stream and grades are below 2 percent, which is typical of most freeway segments in the Los Angeles and San Diego areas, the effect of a large truck is usually equivalent to that of 1.5 to 2.0 passenger cars. On long grades, such as those found on some San Francisco area freeway segments, the effect can be substantially more—equivalent to that of 4 to 8 passenger cars.

Trucks also have an effect on traffic flow in adjacent lanes. The headway between passenger cars increases slightly as car drivers pass a truck. The effect is thought to be caused by the truck's size (which restricts the passenger car driver's field of view), noise impacts, and psychological factors. This adjacent lane friction effect increases the impact of trucks by the equivalent of 0.1 passenger cars per adjacent lane.

The perceived effect of large trucks is greater than that calculated by traffic engineers because of the large size of trucks relative to passenger cars and the high visibility of trucks in the traffic stream. These factors contribute to a psychological, if not an actual, barrier to passenger car drivers' entering and exiting the freeway. In California, as in many other states, trucks are restricted to the rightmost lanes and are prohibited from using the leftmost or median passing lanes except where necessitated by left-hand exits and merges. This regulation increases the density of trucks in the rightmost lanes. Where there are large volumes of traffic entering or exiting the freeway, trucks tend to dwell in the second lane to avoid frequent lane and speed changes caused by merging traffic. This practice creates a barrier to merging traffic. Research on this effect is limited and inconclusive but indicates that, when the freeways are saturated during peak periods, trucks and automobiles stay in the acceleration lanes longer than normal, and many merges are forced. It is likely that this condition contributes to sideswipes and rear-end accidents when traffic flow is unstable.

Truck Accidents and Incidents

In the Los Angeles, San Francisco, and San Diego areas, truck accidents (such as collisions and jackknifes) and truck incidents (such as breakdowns, spills, and shifted loads that force trucks to stop on the freeway) cause 19 million vehicle-hours (veh-hr) of delay per year, at a cost of over $200 million. Accidents and incidents involving large trucks during the peak periods are estimated to account for 5 million veh-hr of delay at a cost of over $50 million per year.

It has been estimated that the total delay cost of congestion in Los Angeles is about $1 billion per year. Of this, $500 million is attributed to recurrent congestion (predictable delay caused by the high volume of traffic on the freeways). The other $500 million is attributed to nonrecurrent congestion (unpredictable delay caused by accidents and incidents). Truck-involved accidents are estimated to account for $100 million, about 20 percent of the total cost of nonrecurrent congestion.

Major incidents, which constitute 5 to 10 percent of all truck incidents, are thought to be responsible for about half of the total delay caused by truck incidents. A major incident is defined as an incident or accident that blocks two or more lanes of the freeway for 2 hr or longer. Recker et al. (*1*) estimate that the average duration of a major incident is 3 hr, 39 min; it triggers an average of 2,800 veh-hr of delay on the freeways around it. A few of these major incidents last 10 to 12 hr, triggering 30,000 to 40,000 veh-hr of delay. About two-thirds of major incidents are the result of overturns, spills, and shifted loads. These incidents tend to occur on ramps, and the primary cause is excess speed on the curve. Most major incidents occur before the peak periods—at dawn or during midday when trucks and other vehicles are operating at full freeway speeds before congestion reaches its peak.

Common incidents, which constitute 90 to 95 percent of all incidents, are thought to be responsible for the other half of the total delay caused by truck incidents. The average duration of a common incident is 1 hr, but it triggers an average of 1,200 veh-hr of delay (*1*). Half the common incidents are caused by breakdowns, stalls, broken fan belts, and flat tires, and 27 percent are caused by accidents. Most of the accidents involve sideswipes and rear-end collisions in the travel lanes, and many occur during the peak periods.

Most truck accidents and incidents occur on weekdays during the midday period, which is when truck volumes on the freeways are highest. It is estimated that 90 to 95 percent of all major and common incidents occur on weekdays, 70 to 80 percent during the daytime, and about 50 percent during the midday period.

Truck accidents and incidents are concentrated on a few heavily traveled freeways. In each of the metropolitan areas, three freeways account for nearly 50 percent of the total incidents and vehicle-hours of delay. In Los Angeles, four freeways account for 67 percent of the total number of vehicle-hours of delay caused by truck-involved accidents: I-5 accounts for 29 percent, US-101 for 13 percent, I-405 for 13 percent, and I-10 for 12 percent.

MANAGEMENT STRATEGIES

The study identified and screened a large number of freeway and truck management techniques. Three evaluation criteria were considered: potential to reduce peak-period freeway congestion and truck-involved accidents, applicability of the technique to California freeways, and feasibility. The assessment of feasibility took into consideration technical, legal, and budgetary constraints. The overall assessments were as follows, where + + indicates significant reduction of congestion or accidents, feasible; + indicates moderate reduction of congestion or accidents, feasible; ? indicates feasibility uncertain; and – indicates not technically or legally feasible at this time.

- Truck restrictions
  - – Peak-period bans
  - + ? Freeway section bans
  - ? Route diversions
  - + Designated access routing
  - + Hazardous materials route restrictions
  - + Local truck and noise ordinances
- Road pricing
  - – Peak-period permits
  - + ? Freeway permits
  - + + ? Peak-period tolls
  - + Peak/offpeak rate differentials
- Traffic engineering
  - + Lane designations and restrictions
  - + ? Wider lanes
  - + + Continuous merge lanes
  - + + Variable message signs
  - + + Sign placement
  - + Truck advisory signs
  - + ? Speed restrictions
- Road design and construction
  - + Capacity and safety improvements
  - + + Improved entry/exit ramps and merges
  - + + Continuous-merge lanes
  - + ? Exclusive truck facilities
    Peak-high-occupancy-vehicle (HOV)-only/offpeak truck-only lanes
- Fleet management
  - + Voluntary offpeak operations
  - + Automatic vehicle location/computerized routing
  - + Driver training and management
- Shipper/receiver actions
  - + Voluntary offpeak operations
  - + + ? Mandatory offpeak operations
- Incident management
  - + Automated detection
  - + + Site and area surveillance and communications
  - + + Equipment and procedural improvements
  - + Organizational changes
- Inspection and enforcement
  - + ? Automated surveillance
  - + Urban truck inspections and enforcement
- Information management
  - + ? Highway advisory radio
  - + ? Traffic information

Four strategies were developed, incorporating the leading techniques from this list. The strategies were (a) traffic management, (b) incident management, (c) night shipping and receiving, and (d) peak-period truck bans. Although approval for a peak-period freeway truck ban was judged to be unlikely under the provisions of the Surface Transportation Assistance Act of 1982 (STAA), it was included and assessed for the following three reasons:

1. Truck bans are widely perceived by the public and the media as a direct and appropriate response to peak-period congestion.
2. There were no data on the effects of a truck ban on freeway congestion.
3. At the time the strategies were formulated, the city of Los Angeles and the South Coast Air Quality Management District (SCAQMD) were actively considering a peak-period freeway ban.

The city subsequently announced a truck permit program that would restrict the number of large trucks that could use city streets during the peak periods. The street ban was not assessed because (a) adequate data were not available (the city is now collecting the necessary data), (b) the restrictions affect only a portion of the metropolitan area, and (c) the street ban would be difficult for the state to pursue on a regionwide basis.

Although the strategies are evaluated separately, they are not mutually exclusive. An effective freeway and truck management program could use elements from several of these strategies.

TABLE 2 COMPARISON OF FREEWAY AND TRUCK MANAGEMENT STRATEGIES ($ MILLIONS ANNUALLY)

			Economic Impacts(1)					
			Direct:					
Strategy	Feasible	Freeway Congestion Relief	Motor Carriers(2)	Other Vehicles(2)	Shippers/ Receivers(3)	Indirect: CA Business Sales(4)	Air Quality(5)	Implementation Cost(6)
Traffic Management(7)	Yes	++	$8	$121	+	} $8	+	$20-40
Incident Management(7)	Yes	+	$4	$44	+		+	$3-5
Night Shipping and Receiving(8)	Maybe	+	$3	+	-$2,200	-$913	+	$2-3
Peak Period Ban -- Core Freeways(8,9)	Unlikely	+	-$43	$7	-	-$28	-	$2-3

Notes:

++ Significant positive impact
+ Modest positive impact
- Modest negative impact

(1) 1988 Dollars
(2) Time and vehicle operating cost savings (+) or cost increases (-)
(3) Logistics cost savings (+) or cost increases (-)
(4) Changes in volume of business sales (output) in 1988 relative to baseline forecast
Traffic and incident strategies were combined because their individual direct (motor carrier) impacts were too small to be modelled reliably
(5) Not quantified
(6) Ten-year annualized implementation costs
(7) Los Angeles, San Francisco, and San Diego
(8) Los Angeles and San Francisco only
(9) Assumes 80 percent of peak period truck miles of travel are diverted to arterials; 20 percent diverted to offpeak periods (midday or night)

The strategies and their estimated direct and indirect effects are described in the following paragraphs and summarized in Tables 2 and 3.

Traffic Management

A traffic management program could reduce congestion by smoothing the flow of traffic. This result would be achieved by a combination of traffic management and freeway design measures, such as adding continuous-merge lanes at critical locations, redesigning high-accident ramps, providing information to drivers about traffic conditions ahead, regulating speed and lane use, and enforcing safe truck operation. A traffic management strategy would focus on problems related to large trucks, but the traffic and safety benefits would accrue to all freeway users.

Six techniques were identified as having the greatest potential for reducing freeway traffic congestion by addressing the problems unique to large trucks. The first involves sign placement. Drivers have a difficult time detecting and reading directional signs, particularly exit signs, when large trucks block their field of view. This difficulty decreases the time drivers have to anticipate and safely execute lane changes. On congested freeways, it contributes to sideswipe and rear-end collisions. To counteract this problem, additional signs should be placed to the left side of the freeway, on overhead structures, or in the median in advance of difficult exit situations.

The second technique employs variable message signs. Caltrans has installed these signs alongside freeways in several locations in the larger metropolitan areas. Variable message signs are used to alert drivers to accidents, queues of stopped vehicles, severe congestion, and speed restrictions. Through the traffic management program these signs could be installed in many locations and intensive use could be made of individual lane signs to assign trucks to lanes, control traffic flow at merges, and regulate traffic speeds.

The third technique consists of speed restrictions. Many truck accidents occur at ramps because trucks attempt to take the curves at too high a speed. Therefore, ramps could be posted with safe speed limits for trucks. Rear-end collisions are frequently the result of unstable, stop-and-go traffic flows. Variable message speed signs could be used to dampen speed oscillations, giving drivers of large trucks adequate time to brake safely.

Additional lanes and lane restrictions for trucks constitute the fourth technique. Trucks are required to use the rightmost lanes of the freeway, where the pavements have been strengthened in anticipation of heavier truck loads. When the proportion of trucks in these lanes is high, it creates a psychological, and sometimes physical, barrier for drivers trying to merge and contributes to sideswipes and rear-end collisions. To mitigate this effect, an additional continuous-merge lane could be constructed along the breakdown lane where traffic volumes warrant and space permits. Large trucks would be excluded from this lane except at entrances and exits.

The fifth technique is improved entrance and exit ramps. On some older freeways, entrance and exit ramps do not provide adequate deceleration and acceleration lanes. In addition, some ramps are not properly banked for today's larger

TABLE 3 COMPARISON OF FREEWAY AND TRUCK MANAGEMENT STRATEGIES: ECONOMIC IMPACTS BY REGION ($ MILLIONS ANNUALLY)

	Economic Impacts by Region					
	Direct(1):			Indirect: Business Sales(2)		
Strategy	Los Angeles	San Francisco	San Diego	Los Angeles	San Francisco	San Diego
Traffic Management(3,5)	$74	$44	$11	} $4.4	2.4	$0.48
Incident Management(3,5)	$28	$16	$4			
Night Shipping and Receiving(4,6)	-$1,450	-$710	n/a	-$580	-$290	-$15
Peak Period Ban -- Core Freeways(4,5)	-$22	-$14	n/a	-16.6	-$10	-$0.35

Notes:
(1) 1988 Dollars
(2) Changes in volume of business sales (output) in 1988 relative to baseline forecast.
Changes for 'all other areas' in CA are not shown in this table. See Table 1 in Chapter III of Summary Report.
Traffic and incident strategies were combined because their individual direct (motor carrier) impacts were too small to be modelled reliably
(3) Los Angeles, San Francisco, and San Diego
(4) Los Angeles and San Francisco only
(5) Time and vehicle operating cost savings (+) or cost increases (-)
(6) Logistics cost savings (+) or cost increases (-)

and heavier trucks. These problem ramps could be earmarked for an accelerated redesign and reconstruction program.

The last technique involves mobile truck safety inspection teams. The California Highway Patrol (CHP) maintains a network of truck inspection stations on intercity freeways, but there are few urban inspection stations. Land is expensive, truckers can use arterials to avoid the stations, and truck movements in and out of the stations cause congestion. The use of mobile truck safety inspection teams (a concept already being demonstrated by CHP) could be expanded along freeways that have a high proportion of large trucks and accidents.

The traffic management program would focus on the most congested freeways in the core of each metropolitan area: about 150 mi of freeway in Los Angeles, 84 mi in San Francisco, and several dozen miles in San Diego. It is estimated that an aggressive traffic management program in these areas could realize a 15-percent reduction in the vehicle hours of delay caused by recurring congestion (a 25-percent reduction on the core area freeways but less on the outlying freeways). The estimate takes into consideration that these three metropolitan areas already have traffic management programs in place for portions of their freeway systems. The techniques proposed for the traffic management strategy would build on and complement current traffic programs, such as the Los Angeles Smart Streets project for the I-10 corridor, the San Francisco traffic operations center project, and the Heavy-Vehicle Electronic License Plate Program (HELP).

The direct benefits to all highway users, measured in time and vehicle operating cost savings, would be about $74 million per year in Los Angeles, $44 million per year in San Francisco, and $11 million per year in San Diego. The differences in the savings reflect the different sizes of the metropolitan areas; the savings per vehicle would be about the same in each area.

Time savings provide most of the benefits in the traffic management strategy. The calculations assume that the value of time for motor carriers is $20/hr; the weighted average for all vehicles is $10/hr. The benefits from time savings are offset by small increases in vehicle operating costs. Stop-and-go driving on congested freeways is costly: speed oscillates up and down, and wear and tear on tires and engines increases. Smoother traffic flows reduce these operating costs, but the savings are lost as freeway speeds increase. As speed increases, fuel consumption increases significantly, increasing total vehicle operating costs, too. These costs would be small compared with the value of time savings.

The traffic management strategy would have several additional effects that are not quantifiable. A successful program would increase the total volume of peak-hour traffic. By reducing congestion and increasing freeway speeds, the program would make peak-period travel marginally more attractive than it is today. This change would cause some drivers to shift their trips from the shoulders of the peaks into the peak periods, and a few drivers would make more trips during this period than they do now. No attempt has been made to estimate the elasticity of demand for peak-period travel with respect to travel time because little information is available to support the analysis, but the direction of the effect is clear. Finally, although a traffic management strategy would not decrease the number of large trucks in peak-period traffic, it would likely result in modest air quality improvements (by reducing stop-and-go traffic) and significant safety improvements (by reducing hazardous traffic situations).

Incident Management

An incident management program could reduce congestion and delay by significantly reducing the time required to locate and clear incidents and accidents from the freeways. Caltrans and CHP have established an excellent program for managing accidents and incidents; however, the resources allocated to the major incident response teams and system-level traffic management have not kept pace with the growth in traffic and congestion on the freeways. The incident management strategy would recapitalize and expand current programs.

There are four key elements in the incident management strategy. The first is improved surveillance and communication. Incident management, like emergency medical service, is most effective when problems can be diagnosed and stabilized in their early stages. Information about the type of truck, its position, traffic on the freeway, and conditions on parallel arterials is critical. The incident management program could use closed-circuit television and data links (along the freeway or mounted in planes and helicopters) to bring information to incident management teams before they are dispatched to a site so decisions on equipment, personnel, and system-level traffic management could be made in a timely manner.

The second element involves equipment and procedures. Prepositioning of heavy-duty tow trucks; helicopter delivery of emergency equipment and personnel; video recording of accident scenes to speed up documentation for administrative, legal, and insurance reports; and similar techniques could be applied to facilitate work at accident sites.

System operations management is the third element. The incident management program could make extensive use of computers to monitor system traffic flows, test incident management plans, and evaluate the effectiveness of the program.

The fourth element includes organization and coordination. Caltrans and CHP have well-coordinated operations, but major incidents often involve police, fire, and emergency medical personnel; hazardous materials experts; traffic engineers; maintenance workers; and mechanics from different agencies and jurisdictions. The incident management strategy could strengthen the institutional capabilities to coordinate and manage these large teams effectively.

The incident management strategy could reduce the duration of major incidents, which may account for 5 to 10 percent of all incidents, by 50 percent (from an average of 4 hr to an average of 2 hr) and the duration of common incidents, which may account for 90 to 95 percent of all incidents, by 20 percent (from an average of 1 hr to an average of 50 min). These changes would reduce the total number of vehicle-hours of delay resulting from truck-involved accidents and incidents by 25 percent, a savings of about 4.4 million veh-hr of delay per year. The savings would be 2.6 million veh-hr of delay per year in Los Angeles, 1.5 million in San Francisco, and 0.4 million in San Diego. The direct benefits to all highway users would be $28 million per year in Los Angeles, $16 million per year in San Francisco, and $4 million per year in San Diego.

The portion of these costs and benefits that accrues to motor carriers affects the cost of goods movement, which affects the cost of doing business, which in turn affects the competitive position and earnings of businesses and industries in regional, national, and international markets. These changes, which reverberate throughout the economy, can be measured in terms of changes in employment, personal incomes, and business sales or output. The indirect economic effects of the savings generated by the traffic and incident management programs (combined for analysis because the individual savings were small relative to the regional and state economies) would be modest, but positive, on the metropolitan and California economies. Employment and personal income would rise, and it was estimated that total business sales (output) in California would increase by $7 million in 1988 and $31 million by 1995. The traffic management program would account for about two-thirds of these effects and the incident management program for about one-third.

Night Shipping and Receiving Strategy

A night shipping and receiving strategy could reduce congestion by requiring that establishments do most of their shipping and receiving at night. Two segments of the population would be candidates for night operations: large establishments, for which the additional cost would be relatively small and could be spread over many operations, and establishments that normally operate 16 to 24 hr a day (for example, oil refineries, large warehouses, and continuous manufacturing operations). Within these segments, businesses and industries that have their own private fleets and could control shipping and receiving schedules would have the greatest flexibility to shift to night operations. Some, such as supermarket chains, have already done so. Other establishments would be encouraged, but not required, to make this change. For most small manufacturers and retail stores, the labor costs for night operations would be prohibitively high relative to their total labor and operating costs. For others, such as construction firms, night shipping and receiving may be feasible only on large projects where lighting can be installed to ensure safety.

In Los Angeles, 56,000 of 263,000 establishments are large or normally operate at night. An estimated 17,000, or 30 percent, of these establishments would be capable of shifting a significant portion of their shipping and receiving to night operations. (This estimate is based on the authors' professional judgment as well as interviews with shippers and receivers. The full social and economic effects of this strategy are not easily estimated; more industry-by-industry interviews could refine the estimated participation rate.) In San Francisco, 27,000 of 132,000 establishments are large or multishift operations and would be eligible for this change; an estimated 8,000 would be capable of shifting. In San Diego, 8,000 of 42,000 establishments are large or multishift operations and would be eligible, whereas an estimated 2,500 would be capable of shifting. It was assumed, however, that San Diego would not institute a night shipping and receiving program because of the relatively low proportion of large trucks on its freeways.

The truckload movements for these establishments would be the easiest to shift—an estimated 50 to 60 percent could be shifted. Less-than-truckload (LTL) movements would be more difficult to shift because their schedules are determined by the demands of many shippers and receivers, and LTL carriers are dependent on the economies of scale provided by dense pickup and delivery routes. It was estimated that only 10 to 20 percent of LTL movements could be shifted economically to night operations.

The additional cost to shippers and receivers for night operations would be about $75,000 per establishment per year, or $300 per day over a 250-operating-day year. The cost would cover building overhead (heat, light, and power), security (a security guard to protect against theft), management (a portion of a shift supervisor's time), and administration (a portion of a receiving clerk's time). General management and overhead costs would add another $1 per employee in these establishments. There would be considerable variation across establishments and industries, with some firms incurring high costs and others marginal costs. Some firms could offset the additional cost with operational savings, but it is believed that many of the large firms that stand to realize significant savings from night shipping and receiving have already taken steps to capture these benefits. For most firms, mandatory night shipping and receiving would increase the cost of doing business. The total estimated costs to shippers and receivers would be $1.45 billion in Los Angeles and $710 million in San Francisco.

A secondary cost to shippers and receivers would be the cost of delayed shipments. Most firms ship in the afternoon at the end of a day's production with the expectation that the shipment will be delivered the next morning. California's freeway system makes it possible to ship from Los Angeles in the evening and receive in San Francisco the following morning. Many businesses and industries depend on this level of service to keep inventory costs down. If pickups are delayed until night hours, a high proportion would not be delivered in the morning. Most LTL shipments and many truckload shipments between Los Angeles and San Francisco would lose a full day's production time. The cost of such a delay is approximately 0.04 percent of the value of the shipment affected. It is estimated that an aggressive mandatory night shipping and receiving program could affect 20 percent of shipments, at an annual cost of $24 million in Los Angeles and $11 million in San Francisco.

The direct cost impacts of a night shipping and receiving program would vary by the type of carrier and the industry it serves. In general, truckload carriers, both for-hire and private fleets, would realize modest benefits from night operations. Labor and administrative costs would increase, but time savings and operating efficiencies would likely offset these. This would not be the case for LTL carriers. Pickup and delivery operations account for 10 to 30 percent of total transport costs for these carriers. The denser the pickup and delivery operations, the less costly they are to perform. If a significant proportion of shipments were to be picked up or delivered at night, the LTL carrier would have to "plow the same field twice." Preliminary estimates indicate that a two-shift operation for LTL carriers could increase costs 15 to 35 percent. Some of this increase would be offset by service and operational innovations developed in response to a night shipping and receiving program. However, because it is unclear how carriers would adapt to night operations and because the proportion of LTL shipments involved in night operations would likely be modest, no dollar value has been placed on the additional costs for LTL operations.

A night shipping and receiving program would have modest effects on traffic and congestion. The total truck-miles of travel in the metropolitan areas would increase slightly, particularly for LTL operations. Some truck movements would shift out of the peak, but most of the truck movements, particularly the truckload movements, would probably be shifted out of the less congested midday offpeak period. The benefits to commuters on the freeways would be modest. The annual value of time savings would be in the range of $2 to $4 million in Los Angeles and $0.7 to $1.5 million in San Francisco.

The air quality benefits of a night shipping and receiving program would likely be positive, but they were not quantified. Trucks that shifted to night operations would operate at higher average speeds and generate somewhat less air pollution because smaller amounts of the diesel emissions would be exposed to sunlight.

The additional costs to shippers and receivers would change the cost of doing business in Los Angeles and San Francisco. It was estimated that the indirect economic effects of these cost changes would decrease total California employment by 11,300 jobs (−0.1 percent) in 1988 and 31,500 jobs (−0.2 percent) by 1995. Without offsetting savings, total business sales or output would decrease by an estimated $0.9 billion (−0.1 percent) in 1988 and $3.4 billion (−0.3 percent) by 1995.

Implementation of a night shipping and receiving program would depend on the ability of state and local governments to require shippers and receivers to change their operating patterns. The California legislature recently granted SCAQMD the power to regulate shipping and receiving as an indirect source of truck emissions. This power could provide the regulatory basis for the night shipping and receiving strategy. SCAQMD is considering a night shipping and receiving regulation patterned after its ridesharing program, which is targeted at businesses that have a large number of employees. The program involves information programs, mandatory preparation of ridesharing plans, and the threat of enforcement through regulatory actions and fines.

The direct target of a night shipping and receiving program would be shippers and receivers, but the acknowledged objective would be to regulate truck movements to reduce air pollution. This regulation would likely be challenged as interfering with Interstate commerce. Resolution of the two conflicting federal mandates, to achieve clean air standards and to minimize interference with Interstate commerce, will require congressional or judicial action.

Peak-Period Freeway Truck Ban

Peak-period freeway truck bans could reduce congestion by excluding large trucks from core area freeways during the morning (7:00–9:00 a.m.) and evening (4:00–6:00 p.m.) peak periods. In Los Angeles, the ban would affect 150 mi of freeway bounded by the Ventura Freeway and SR-134 on the north, I-605 on the east, and I-405 on the south and west. In San Francisco, the ban would affect 84 mi of freeway in the city, on the San Mateo peninsula, and in the East Bay. A San

Diego ban would affect several dozen miles of freeway at the center of the region.

The ban would force motor carriers to divert to parallel arterials, shift operations to offpeak periods, increase their use of two-axle trucks not embargoed by the ban, and, in a few cases, shift the location of terminals and drop-points. The majority would divert their trips to parallel arterials because their customers would find it too costly to remain open for nighttime shipping and receiving. An estimated 80 percent of truck trips affected by a peak-period ban would be diverted to parallel arterials, and 20 percent would be shifted to offpeak periods (midday or night). Those trips shifted to the offpeak would primarily be truckload operations because the cost of shifting LTL would be prohibitively high for most shipments.

Because of the capital cost and the loss of efficiency, few carriers are expected to switch to two-axle trucks. A two-axle truck is less maneuverable than a three-axle city tractor towing a 28-ft pup trailer. It is also not as cost efficient because it has less cargo space and its cargo must be transferred to a trailer for long-distance line-hauls. A peak-period ban affecting freeways and city streets would make two-axle trucks much more attractive. Extensive use of two-axle trailers would tend to increase the truck miles of travel.

A peak-period freeway truck ban would increase average speeds on the core area freeways. For example, in Los Angeles, average freeway speeds would increase from about 40 to 42 mph during the peak periods. A typical Los Angeles freeway carries 1,700 passenger cars and 50 large trucks (3 percent of total volume) per lane per hour. Because each truck is equivalent to 2.0 passenger cars, the total traffic volume is equivalent to 1,800 passenger cars per lane per hour. At that volume, the average freeway speed is 40 mph. A peak-period freeway truck ban would remove 50 trucks, or 100 passenger car equivalents, decreasing the total volume to 1,700 passenger cars per lane per hour and increasing the average freeway speed to 42 mph. Experience has shown that this gain will be short-lived in a saturated system. As peak-period travel conditions improve, drivers tend to shift from the shoulders of the peak period back into the peak period, shortening queues at bottleneck locations slightly. Most of the congestion relief from a peak-period freeway ban would likely be lost within 6 weeks to 6 months.

In Los Angeles, the value of time saved by all vehicles remaining on the freeways would be $19 million per year. These benefits would be offset by increased costs to motor carriers and to vehicles affected on the arterials. The additional time and operating costs would be $28 million for motor carriers and about $12 million for automobile drivers on the arterials. The net direct cost impacts of a freeway truck ban would be $22 million in Los Angeles and $14 million in San Francisco. These estimates do not include cost changes for the 20 percent of large-truck trips shifted to offpeak periods. These carriers would realize marginal savings from operating under less-congested conditions but would accrue offsetting marginal costs for night operations.

The additional costs to motor carriers would affect the cost of doing business. It was estimated that the indirect impacts of these cost changes would reduce total California business sales (output) by $27 million in 1988 and $118 million in 1995.

A peak-period ban would also have direct impacts on safety and air quality. Accident and incident rates would decrease on the core area freeways but would increase on the parallel arterials due to the diversion of truck travel. Because the road conditions and speeds are different, the types and mix of accidents and incidents would change. Responsibility for these incidents would shift from state agencies to local agencies.

Approval for a peak-period ban on large-truck travel on freeways is unlikely under the provisions of the STAA, the Tandem Truck Safety Act of 1984 (TTSA), and subsequent court decisions. The STAA designated a national network of highways (including most California freeways) and prohibited state restrictions on large-truck operations on these routes unless the Secretary of Transportation finds significant safety problems on Interstate routes or significant safety, environmental, and operational problems on federal-aid primary routes.

A number of states have challenged the STAA. The challenges have included attempts to prohibit doubles, restrict trucks to specified routes, prohibit peak-period operation of large trucks, and require special permits for the operation of large trucks. In these cases, the courts have overruled state attempts to restrict the movement of large trucks that otherwise comply with the STAA and TTSA regulations. In several instances, the courts have been sympathetic to state arguments in favor of restricting large-truck movements on certain highways, but they have consistently ruled that the language of the STAA and TTSA does not permit the states to take these actions. The courts have interpreted the acts as permitting truck restrictions only when substantial safety problems can be demonstrated.

Truck bans on specific, accident-prone freeway segments are possible, but FHWA has approved only one truck ban (of limited duration) since the STAA was enacted. An areawide ban aimed at reducing air pollution has not been tested with FHWA or the courts.

CONCLUSIONS

Large-Truck Impacts on Freeway Congestion

The volume of large trucks on the freeways does not have an inordinate effect on peak-period congestion. Peak-period congestion is created primarily by the high volume of automobile traffic. Truck traffic makes a relatively small contribution to that congestion except on those few, highly congested freeways where truck volumes exceed 10 percent of total vehicles. Removing large trucks from most freeways would increase average speeds by only a few miles per hour.

On the other hand, truck-involved incidents and accidents do have a significant impact on freeway congestion. They account for about 20 percent of the delay accruing from all vehicle incidents and accidents, and they are highly visible to motorists and the public. Major truck incidents, which are of most concern, are few, but their impacts can be catastrophic and can trigger gridlock.

Traffic Management

A traffic management strategy is feasible and can be built on existing programs. Such a strategy would directly address the problem of freeway congestion and would provide positive benefits to freeway users and the economy. A traffic management strategy would not reduce the number of large trucks in peak-period traffic, but it would likely result in modest air quality benefits (by reducing stop-and-go traffic) and significant safety improvements (by minimizing hazardous traffic situations).

Incident Management

An incident management strategy is also feasible and can also be built on existing programs. It would address the public's concern about freeway gridlock and provide positive benefits to freeway users and the economy. An incident management strategy would reduce delay from truck-involved incidents and accidents, but it would not address the problem of recurring congestion. To be most effective, an incident management program should be paired with a traffic management program.

Night Shipping and Receiving

A night shipping and receiving program may be feasible in Los Angeles if it can withstand legal challenge and garner industry support. The California legislature has granted SCAQMD the power to regulate shipping and receiving as an indirect source of truck emissions, but such a program may be challenged as interfering with Interstate commerce. Resolution of the conflicting federal mandates (to facilitate Interstate commerce and reduce air pollution) may require congressional or judicial action. The full social and economic impacts of this strategy are not easily estimated; however, it is clear that the economic impacts will be costly unless the program is directed toward businesses and industries that can find offsetting savings. This will necessitate the strong participation of shippers and receivers in the design and implementation of the program. The strategy would have a modest effect on peak-period congestion, but it may improve air quality by reducing truck emissions during daylight hours. The strategy warrants more detailed study.

Peak-Period Freeway Truck Ban

A peak-period ban on large-truck travel on the freeways would have modest negative impacts on motor carriers, the economy, and air quality (engine emissions would increase as trucks divert to slower arterial routes). Average freeway speeds would increase slightly, but a ban would not provide significant relief from peak-hour congestion. Approval of a peak-period freeway truck ban is unlikely under the provisions of the STAA and subsequent court decisions. The courts, citing the federal supremacy clause, have consistently struck down state laws that have attempted to impose truck bans based on general concerns about congestion and safety. Truck bans on specific, high-accident freeway segments are possible, but FHWA has approved only one ban (of limited duration) since the STAA was enacted. An areawide ban aimed at reducing air pollution has not been tested with FHWA or the courts.

RECOMMENDATIONS

At the conclusion of this study, the following recommendations were made to the state of California.

Programs

- The state should expand and improve its incident management programs in the Los Angeles, San Francisco, and San Diego areas.

As a first step, Caltrans and CHP should undertake a joint review of their current incident management programs. Using this review as a base, they should develop a list of improvements (including those suggested in this paper) in the areas of surveillance, communications, site procedures, organization, and management. The improvements should then be tested and demonstrated to establish their feasibility and cost-effectiveness. Other state and local agencies that are involved in incident management should participate in the development program to encourage innovation and disseminate new techniques as rapidly as possible. The state should continue and strengthen its efforts to prevent accidents and incidents through its licensing, equipment maintenance, and safety inspection programs.

- Concurrently, the state should expand and intensify its traffic management programs in all three areas.

Caltrans should review its current traffic improvement programs to ensure that they give explicit consideration to the needs of large-truck operators and to the effects of these trucks on traffic flow. Special attention should be given to signage, speed controls, and the design of ramps and continuous-merge lanes. Congested freeways with high volumes of large trucks should be assessed and targeted for intensive truck-traffic management. In the San Francisco East Bay area, I-880 (the Nimitz Freeway) should be considered for use as a demonstration site for the truck-traffic management program. It is a congested freeway that carries a high volume of trucks and has a high accident rate. It is already a candidate for traffic management improvements and would provide an early opportunity to evaluate the effectiveness of truck-traffic management actions.

- The state should support a pilot program in Los Angeles to determine if a cost-effective night shipping and receiving program can be developed.

The program should focus on one or two high-truck-volume industries and determine if there are regulatory, tax, or operational changes that could make offpeak shipping and receiving economically attractive to firms. The pilot program should have a working council representing business, industry, motor carriers, and government. The working council should provide a forum for technical work as well as program development. As part of this program, Caltrans should monitor the progress of the night shipping and receiving program proposed by the city of Los Angeles (requiring large shippers and receivers to operate their docks for at least 4 hr between the hours of 8:00 p.m. and 6:00 a.m.).

- The state should not pursue areawide freeway truck bans; however, it should research time-of-day and lane restrictions.

Caltrans should conduct additional research on truck-involved incidents and traffic flow under congested conditions to determine whether there is a safety justification for time-of-day and lane restrictions on specific, high-accident freeway sections.

- The state should collect data and improve traffic modeling procedures used to estimate the impact of trucks on air quality.

The assessment of air quality impacts was not part of the scope of this study, but it is an important element of freeway and truck management strategies for Los Angeles. Available data on truck movements are inadequate, and current traffic models do not adequately distinguish trucks from other vehicles. New data and more responsive analytical tools must be developed.

Policies

This study provided new data and new insights on the relationships between large trucks and urban freeway congestion, and it put California at the leading edge of efforts to develop new solutions to urban freeway congestion. The issues of freeway and truck management are complex, and some solutions have significant social and economic costs. A single study, necessarily, leaves many questions unanswered and many options unexplored. Effective and equitable solutions will require a long-term commitment to research and implementation. As transportation policies are developed, it is recommended that the state.

- Encourage the development and coordination of freeway and truck management programs;
- Develop forums through which business, industry, and government can resolve congestion and urban goods movement problems; and
- Promote research and development of technology for highway and truck management.

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REFERENCE

1. W. W. Recker, T. F. Golob, and R. F. Teal. *An Analysis of Truck-Involved Freeway Accidents.* Institute of Transportation Studies, University of California at Irvine, 1988.

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