
Traffic Flow Improvements

Traffic Flow Improvements

■ Introduction

Traffic flow improvements represent those actions that can be implemented to enhance the person-carrying capability of the roadway system, without adding significantly to the width of the roadway. The range of roadway facility actions available generally fall under two classifications. Actions primarily oriented to urban freeways or expressways, and the second oriented to arterial and local streets. Most traffic flow improvements are implemented with a focus on the peak period work trip. However, for many of these actions such as the improvement of arterial signal systems, their applicability could as easily be expanded to include traffic conditions throughout the day.

The primary objective for improving traffic flow is to enhance the efficiency of the existing roadway system and therefore to alleviate traffic congestion and related problems such as air pollution. Other factors motivating their implementation include financial difficulties in supporting new major transportation projects, and the environmental and physical constraints associated with new infrastructure construction. Moreover, there has been a growing recognition that implementing programs consisting of several interrelated traffic flow enhancement strategies can lead to substantial reductions in travel time and delay.

■ Definition of Measures

Traffic flow improvement actions include a range of strategies as summarized in Table 1 from the "Toolbox for Alleviating Traffic Congestion" handbook, prepared by the Institute of Transportation Engineers (8). Among the more common actions are the following:

Traffic Signalization

Traffic signalization represents the most common traffic management technique applied in the United States. It is estimated that of the 240,000 urban signalized intersections in the United States, about 178,000 need equipment and/or timing upgradings. Traffic signal improvements generally provide the greatest payoffs for reducing congestion or travel time delay on local and arterial streets. The basic type of improvements available to improve traffic flow on arterials, include:

Table 1. List of Representative Traffic Flow Improvement Strategies

1. Traffic Signalization

- Equipment or software updating,
- Timing plan improvements,
- Signal coordination and interconnection,
- Signal removal.

2. Traffic Operations

- Converting two-way streets to one-way operation,
- Two-way street left turn restrictions,
- Continuous median strip for left turn lanes,
- Channelized roadway and intersections,
- Roadway and intersection widenings and reconstruction.

3. Enforcement and Management

- Enforcement for all of the actions described in this table,
 - Incident Management Systems,
 - Ramp metering.
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Reference (8)

- (1) **Traffic signal equipment updates-** equipment updates would include new, more modern hardware that would allow for the planning of more sophisticated traffic flow strategies.
- (2) **Timing plan improvements-** signal timing improvements would update the traffic signal timing to correspond to current traffic flows to reduce unnecessary delays.
- (3) **Signal coordination and interconnection-** better interfacing of pre-timed signals or traffic actuated signals or actively managed timing plans or master controllers would enhance traffic progression along corridors and minimize the number and frequency of stops necessary between intersections.
- (4) **Signal removal-** signal removal at intersections no longer requiring signalized stop control would reduce vehicle delays and unwarranted stops.

Traffic signal control technology, including such applications as computer based control systems, has become very sophisticated. The benefits for improving signals is well documented and leads to tangible reductions in delay and travel times. In states such as California that have instituted aggressive programs to improve signal timing, the results show clear and tangible overall system reductions in vehicular delays, stops and travel times.

Traffic engineers also can use signals to enhance pedestrian mobility and safety, sometimes at the cost of restricting vehicular travel. In cities such as Boston, Oakland and New York where residential neighborhoods abut heavily used and congested highways, selected traffic signals have been purposely not coordinated to increase delay and travel times so as to discourage commuters from using local residential streets to bypass the congestion of the abutting highway. Analogously, traffic engineers can use a "carrot and stick" approach by coordinating signals along certain desirable streets and route alignments to attract or confine traffic to these corridors. Moreover, many municipalities lack an adequate staff of professionals that are able to plan, maintain and update the signal systems in place.

Traffic Operations

Traffic Operations consists of several types of roadway improvement projects.

- (1) **Converting two-way streets to one-way operation** improves corridor travel times and increases roadway capacity by eliminating opposing left turn lanes and providing for better signal coordination. Particularly in many downtown areas where the width of roadways may be inadequate for two-way traffic plus parking and goods delivery, converting to one-way operation and especially in conjunction with other streets to develop a grid circulation pattern can be very beneficial in terms of improving the overall effectiveness of the system.

- (2) **Two-way street left turn restrictions** is a means of eliminating conflicts with left turn movements, thereby reduce congestion and delay for peak periods or for throughout the day. At selected locations where heavy volumes of traffic provide few gaps for left turning movements, the restriction can dramatically reduce queuing and improve the overall capacity of the intersection by as much as 25 to 30 percent.
- (3) **Continuous median strip turn lanes** separate turning vehicles from through traffic by providing a "storage" lane separate from the movement of through vehicles. Where the roadway width permits, the median lane layout can provide overall capacity (and safety) improvements for an arterial corridor that are similar in scale to turning restrictions at an intersection.
- (4) **Channelized roadway and intersections** improves vehicular flow and capacity by clearly marking with striping and signage travel lanes and paths to reduce motorist confusion and uncertainty by channeling traffic in the proper position of the street. They also serve as a "barrier" for opposing streams of traffic.
- (5) **Roadway and intersection widenings and reconstruction** may reduce bottlenecks along sections where traffic capacity is below that of the adjacent street. Roadway and intersection widenings and reconstruction represents a host of traffic flow devices such as improved design, traffic islands, turning lanes and signage to improve the flow of vehicles and the safety of pedestrians. These measures among other benefits help to reduce the number of conflict points among vehicles and help to control the relative speed of vehicles both entering and leaving an intersection. In the Boston Back Bay transportation study, three major intersections that currently exhibit serious congestion were rebuilt based on a new design which eliminated the congestion and improved the level of service of the intersection to conditions considered good (3).

Typically these roadway changes require only signing and pavement marking changes involving little new construction, and therefore are relatively inexpensive and quick to implement. The feasibility and cost of widening a roadway or intersection is largely dependent on whether additional right of way is required. Their implementation is usually based on alleviating a specific traffic problem in a relatively small or local area, and usually to reduce congestion or a bottleneck at one or several specific intersections.

Enforcement and Management

Enforcement and Management consists of several types of programs.

- (1) **Enforcement** for all traffic flow improvements is required to achieve success. Enforcement of traffic and parking program regulations is necessary when individuals are required to change or adhere to a particular travel and parking behavior.

- (2) **Incident Management Systems** may consist of one or some combination of roving tow or service vehicles, motorist aid call boxes, incident teams, detectors in the roadway lanes to monitor traffic volumes, signage systems, traffic operations centers, contingency planning, and improved information availability to consumers through radio and television stations.¹
- (3) **Ramp metering** is a proven technique to improve traffic flow on freeways. Using a modified traffic signal placed at the end of a ramp, metering allows traffic to enter the highway either at pre-timed intervals or at times determined by traffic volumes on the ramp or on the highway. Although additional delays are incurred by the ramp traffic, mainline roadway capacities are protected and the overall travel time or speed is improved.

Because enforcement costs may be substantial, the program is typically earmarked for projects potentially having a major impact on area-wide mobility. For example, a periodic program of enforcement along an HOV lane facility or on a major arterial in the downtown core to eliminate vehicle blockages in intersections or to eliminate double parking.

Highway incident management systems respond to congestion that is recurring (i.e., due to capacity, breakdowns, or operational problems) as well as non-recurring or incident in nature. Recent studies have indicated that on urban freeways, non-recurring congestion may represent about 60 percent of all freeway congestion. A 1986 Federal Highway Administration study indicated that such a system could substantially reduce congestion on approximately 30 percent of the major urban area mileage (5).

Ramp metering typically requires a considerable amount of time to plan and implement. Of particular concern are potential queues that can form on arterials that feed the ramps and generate severe congestion as a consequence of the action. Motorists may choose to by-pass those ramps where metering has been installed to avoid delays. If enough people do so, this diversion could result in the creation of congestion on arterials that may not otherwise have a problem.

As this list suggests, there is a considerable range of actions that are available to improve traffic flow. However, equally apparent is the breadth of their applicability, and the potential that many of these actions could have associated impacts that reduce or obscure their affects on improving air quality. Traffic flow improvement programs typically have been implemented and monitored by traffic planners and engineers, thereby giving emphasis to the potential of these actions to reduce traffic congestion and vehicle delay. While these results would generally have a beneficial affect on reduced vehicular pollutant emissions as well, substantive surveys that focus exclusively on the affects of these measures on air quality have been limited.

^{1/} Incident management is particularly important when traffic is being maintained during the reconstruction of a major roadway. The topic of traffic maintenance during construction is discussed as part of the chapter on Special Events.

■ Examples

Sacramento Signal System Improvement Program

Over the past several years, the City of Sacramento has initiated a series of systematic programs to improve its signalized traffic control systems. The programs have included changing signals that are primarily located in outlying areas from a system of interconnected, pre-timed signals to a system consisting of traffic-actuated signals operated by computer based control. To improve the 220 fixed-time signal intersections located mainly within the Downtown area, the City received direct financial and technical assistance through the California Fuel Efficient Traffic Signal Management (FETSIM) program to re-time and optimize the signal phasing to minimize delay and increase overall arterial travel speeds. A later program is envisioned by the City to install a master computer network that will allow the traffic system to be more thoroughly monitored and controlled from a central site.

The programs were developed and implemented by the City's Department of Public Works and were viewed by the Department primarily as congestion relief measures to increase roadway capacity and travel speeds. On some Downtown streets such as 12th and 16th, the green time is lengthened considerably during peak periods to promote these roadways as commuter arterials and primary Downtown access links to the surrounding regional highway system.

Subsequent surveys identified several positive results. The arterials located in areas outside the Downtown all experienced reductions in vehicle delay averaging about 5 percent (as measured in vehicle hours of travel). Particularly positive is that the benefits are derived throughout the day and not just at peak travel periods. For signalized roadways within the Downtown, the data indicated that the signal timing optimization program has led to an overall travel speed improvement of 10 percent with a comparable improvement in vehicle delay. Vehicle counts for 12th and 16th streets show that the "preferential signal timing" strategy has likely caused traffic to increase on these roadways, along with a higher travel speed during the peak periods. Not determined conclusively was whether this induced demand represent trips diverted from other streets or if the additional vehicles represent new trips.

Back Bay (Boston) Traffic Operations and Management Study

In the Fall of 1987, the City of Boston Transportation Department initiated a comprehensive study of the City's historic Back Bay district to develop a short and long range transportation management policy plan. The Back Bay is home to 16,000 residents. It is also a center of employment with almost 50,000 workers, nearly 6,000 hotel rooms, several major retail centers, and a number of cultural and educational institutions. This diversity is an important strength. However, the great amount of activity that is generated in the area also leads to tremendous competition and congestion within the limited amount of street space available in the area. One of the

study's key objectives to improve traffic circulation reflects this conflict by specifying that while access to the commercial area needs to be enhanced, traffic intrusion in the abutting residential areas must be reduced.

The study identified and analyzed a large number of alternative circulation options. One alternative that was advanced by residents impacted by commuter or non-local traffic was to create an "island" affect to the residential area. This would involve discouraging traffic through such measures as reversing the direction of streets on a block by block basis and modifying traffic signal timings to eliminate coordination and signal progression between intersections, i.e., to dramatically increase travel time and delay for a large Downtown area of the City.

The traffic circulation option that was eventually recommended and implemented achieved the same objective, but through a series of more positive operational and enforcement measures that encouraged desirable travel, rather than discouraging trip making in the area, and also reducing overall travel time and delay in the Back Bay. The plan involved implementing a combination of traffic operational, management and enforcement measures for those arterials that were identified as high priority commuter or through-trip travel routes into and within the area.

The traffic plan primarily focused on two major arterials in the Back Bay, Massachusetts Avenue which runs north and south and Boylston which runs east and west. The traffic operational measures implemented included:

- Left-turn restrictions at several intersections that currently experience a poor level of service;
- Left turn bays at several other locations to reduce conflicts; and
- Street widenings (sidewalk cuts) of a few feet at several sections to gain an additional travel lane or allow for a left turn lane.

Management measures that were implemented involved on-street parking and included establishing new no-stopping zones at selective locations either for the peak period or throughout the day, relocation and consolidation of cab stands, tour bus stops, loading zones and handicapped parking spaces, and removal of short-term parking meters. (Video and time lapse surveys indicated that many metered spaces were occupied long-term by area residents, employees and even by hotel parking valets who were illegally feeding the meters throughout the day.) Enforcement activities featured a highly visible program that included meter maids, motorcycle police officers and tow trucks.

The plan was a reflection of City policy that the primary function of a major arterial is the movement of traffic during periods of heavy travel. The benefits derived from the traffic plan on area mobility were significant. Illegal long-term parking at on-street meters was reduced considerably. Double parking was almost eliminated. Average travel speeds on the arterials increased from as low as 6 mph to over 12 mph (Figure 1).

This resulted in travel time reductions of over 30 percent for both roadways. Significantly, arterial travel times after implementation remained relatively constant throughout the day rather than deteriorate significantly by the afternoon peak period as was the case before the plan was implemented. These travel time reductions were realized despite traffic counts that indicated that the arterials were carrying 30 to 40 percent more traffic during the peak hours. Analogously, traffic counts indicated that other roadways, and particularly several streets located in residential areas, had experienced a corresponding reduction in vehicle use, ranging from 5 percent to more than 40 percent of the peak hour traffic. This substantiated computer traffic forecasts which had been run for each traffic option, and which indicated that significant improvements to the two key arterials would cause traffic to shift from the slower, minor arterials and local streets of the Back Bay. The computer analysis further indicated that while the traffic plan would not reduce total vehicle miles of travel (VMT) in the Back Bay, it would reduce daily vehicle hours of travel (relative to a do-nothing option) by an estimated 5 percent.

Chicago's Incident Management Program

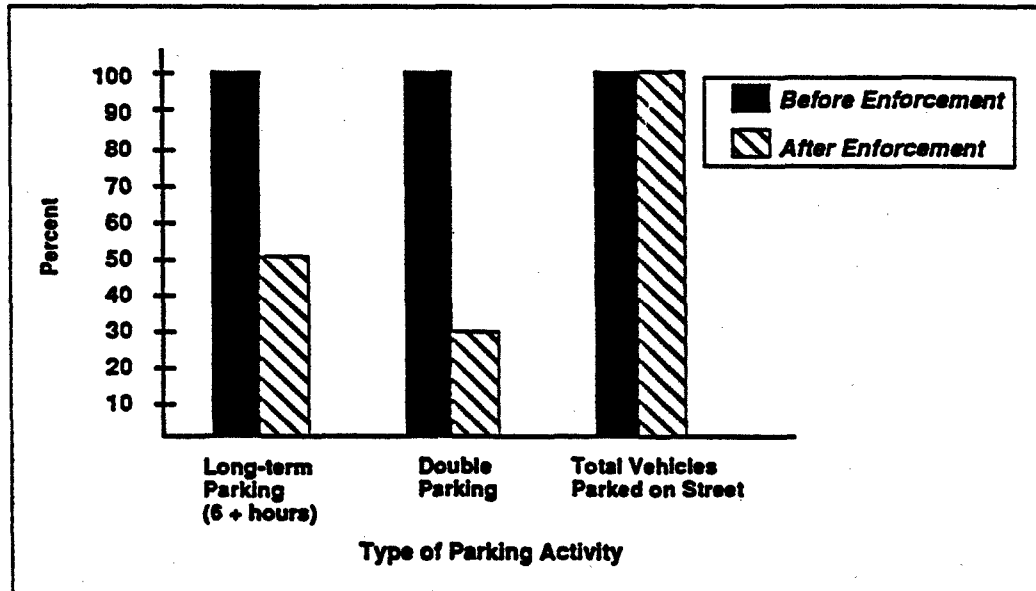
Chicago's incident management program started in 1960 with a crisis on the newly opened Kennedy Expressway (2). Designed to handle 1,500 vehicles per hour per lane, the new highway was quickly swamped as peak-hour traffic volumes exceeded 1,000 vehicles per hour per lane. To manage the crisis, the Illinois Department of Transportation (then the Department of Public Works and Buildings) assigned twenty people in pick-up trucks to the job of patrolling the expressway during the morning and afternoon peak commuter periods. The emergency patrol, eventually named the "Minuteman Patrol," was charged with keeping the Kennedy Expressway open by clearing travel lanes of disabled vehicles. Today the program employs sixty people, covers 80 miles of the 150-mile expressway system, and operates twenty-four hours a day. It has an annual operating budget of \$3.5 million funded from state motor fuel taxes.

The Minuteman Patrol program has survived and grown because the highly visible presence of the service patrol and their focus on personal service has built strong support and a positive reputation for the Minutemen. But maintaining the program has been a struggle.

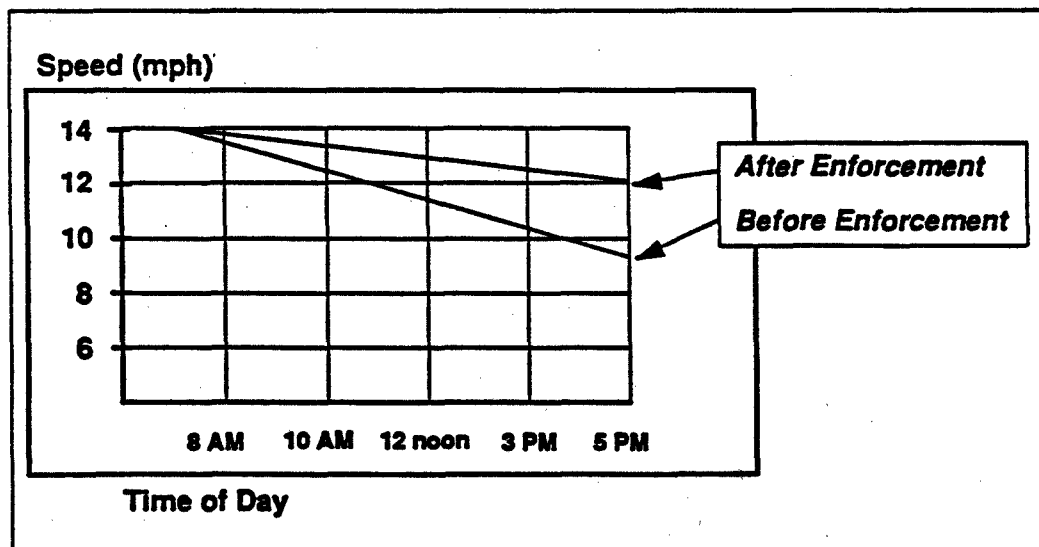
Illinois DOT has never had a formal mandate for the Chicago program. Illinois DOT has a single highway district that covers the Chicago metropolitan area, but the incident management program is a composite of three divisions within the district. The Incident Management Office and the Minuteman Patrol are under the jurisdiction of the Illinois DOT Bureau of Traffic; the communications center under the Bureau of Electrical Operations; and the Transportation Systems Center under its own Bureau of Transportation Systems.

Figure 1. Boston Back Bay Transportation Study, Effects of Traffic Operations and Management Improvements to Boylston Street

Parking Conditions on Boylston Street



Average Travel Speeds on Boylston Street



Source: (3)

In 1988, the Minutemen responded to about 100,000 incidents. Of these 60,000 involved disabled vehicles; 30,000 were for abandoned vehicles, debris on the road, and fires; and the remaining 10,000 were accidents. Programs managers estimate that most incidents, even small breakdowns, are detected within twenty minutes, and clearance times for major incidents have been reduced from four and six hours to about two hours. A critical factor in this is the high level of experience among the Minuteman personnel.

The Minuteman program returns about \$17 in benefits for each \$1 invested in the program. The total program costs \$5.5 million per year. The program saves motorists an estimated 9.5 million vehicle-hours of delay at a value of \$95 million per year.

Illinois DOT removes automobiles and trucks from the expressways as fast as possible. They will do so even if there is a risk that they will further damage the vehicle or its cargo. Illinois DOT generally does not allow motor carriers the right of first refusal to hire their own towing contractors or to hand pick a load before removing a trailer from the expressway, especially during peak periods. Initial concerns about incurring substantial liabilities under the fast removal policy have not materialized. Automobile owners and motor carriers may claim damages from the state, but very few do so. The state police will authorize private tow companies to remove vehicles from the expressways in non-emergency situations; and all vehicles towed by the Minutemen are turned over to private contractors at safe drop sites near the expressways.

Illinois DOT's traffic information services may have as much impact on reducing incident congestion as the patrol and clearance programs. During peak periods, DOT's Traffic Systems Center provides Chicago's commercial radio and television stations with traffic and incident information every five minutes.

Chicago has established an effective incident management program, but it does not have a coordinated regional program. Chicago has no formal mechanism to bring together the managers of the different agencies involved in incident management. Interagency relationships depend on personal relationships built over the years. Observers in Chicago believe that the next major challenge for Chicago is to develop an integrated regional incident management program.

New York/New Jersey Transportation Operations Coordination Committee (TRANSCOM)

TRANSCOM, the Transportation Operations Coordinating Committee, is a public program funded and staffed by its fourteen member agencies, which include the Port Authority of New York and New Jersey, the New York State Department of Transportation, the New Jersey Department of Transportation, and the New York City Department of Transportation (2).

TRANSCOM has fashioned a regional incident management capability for the New York/New Jersey metropolitan area by acting as a value-added provider of information.

TRANSCOM gathers and disseminates information about incidents and traffic conditions. Its clients are ninety-six transportation and traffic enforcement agencies in the metropolitan area. TRANSCOM's services have resulted in improved traffic coordination across the region and a forum for corridor and regional incident planning.

When an incident occurs, TRANSCOM's traffic information center collates information about the incident, assesses its potential traffic impact, and notifies agencies that might be affected. The information is sent directly to agencies and traffic reporting services using alphanumeric pagers, telephone, and facsimile machines.

For the participating agencies, TRANSCOM's service saves time. Operations managers make only one call, rather than ten or twenty, to ensure that notification procedures are set in motion. Notification is immediate; there is a record of the transaction; and the potential for embarrassing oversights is minimized.

Timely information about incidents and traffic conditions is valuable because the regional highway network is saturated, and even moderately severe incidents can trigger substantial congestion. It is also valuable because the region must mobilize many agencies to respond to an incident. The New York/New Jersey region is blanketed with multiple jurisdictions. Within the 500 square miles of the metropolitan area served by TRANSCOM, there are 3 states, 23 counties, over 300 municipalities, and nearly 20 independent authorities. Many of these jurisdictions have several agencies involved in transportation and incident management.

The prospect of gridlock – caused by construction projects intended to solve congestion problems – led to the formation of TRANSCOM in 1985. TRANSCOM's initial mandate was to maintain regional traffic capacity. It was to do this by improving communications among its member agencies about planned improvement projects and coordinating the timing of these projects to assure that parallel routes were not under construction at the same time.

Today, TRANSCOM maintains a comprehensive data base on its member agencies' construction projects. TRANSCOM disseminates a weekly traffic advisory report on regional projects that may have interagency impacts. The advisory report goes out by facsimile every Thursday night so that it is available to the agencies on Friday morning as they prepare for the next week's construction activities. TRANSCOM has recently added information about the completion of projects so that agencies know when traffic restrictions are lifted.

TRANSCOM's traffic information center operates twenty-four hours a day. TRANSCOM's budget has grown to \$1.7 million per year and is now supported by a dozen agencies.

The growth of the program has made it possible for TRANSCOM to expand its role as a broker for corridor and regional contingency planning. The TRANSCOM meetings are the sole forum where New York and New Jersey officials involved in traffic and incident management can meet their counterparts in other agencies and conduct business.

TRANSCOM and the agencies have used this as an opportunity to create corridor level traffic management teams and define formal contingency plans.

TRANSCOM is looking to new services to broaden its constituency and funding base. It is currently working with its agencies to coordinate the use of changeable message signs across the region. TRANSCOM is also trying to target information to specific markets. Under an ATA Foundation demonstration grant, TRANSCOM is providing incident and construction advisories directly to twelve motor carriers that operate in the New York/New Jersey region.

■ Transportation and Air Quality Impacts

Traffic Signalization

Traffic Signalization generally provides the best and most available tool available to reduce congestion on local and arterial streets, although the effects on vehicular emissions can be difficult to quantify.

Actions involving traffic signals focus primarily on improving the efficiency of the roadway system by reducing delays and stops. Therefore, they would improve air quality by providing for higher travel speeds which lower emissions. The information shown in Table 2 from the Federal Highway Administration illustrates the significant travel speed and time benefits available through several types of signal system improvements. Especially impressive are the travel time and vehicle delay improvements that are available through such straight-forward programs to optimize the timings of existing signals or to coordinate signals to provide for signal progression. The data indicate that travel time improvements from 10 percent to 25 percent are possible. Of course, actual results will vary by roadway segment according to the amount of traffic that regularly uses a particular facility and to the extent that the current signal system might already have undergone some form of upgrading.

An important consideration to improving signals is the possibility for inducing additional traffic or increasing the vehicle miles of travel (VMT). As illustrated in the Boston Back Bay study, signal (and other traffic operation) improvements can attract additional vehicles by reducing travel times on affected corridors. In the Boston case study, the additional peak period traffic was diverted from nearby and less socially acceptable routes. This led to an overall increase in travel speeds, although VMT remained unchanged. However, the more fundamental concern in other areas is that motorists might be diverted from alternative modes of transportation, or at a minimum, the signal improvements might induce more and longer trips during peak and off-peak travel periods. The subsequent increase in VMT along a roadway with improved traffic flow would at least partially offset any short term air quality improvements generated by faster, more consistent travel speeds.

Table 2. Traffic Signal Improvements

Before Condition	After Condition	Improvement in Speed or Time
Non-Interconnected, Pre-Timed Signal With Old Timing Plan	Computer Based Control	25%
Interconnected, Pre-Timed Signal With Old Timing Plan	Computer Based Control	18%
Non-Interconnected Signals With Traffic-Actuation	Computer Based Control	16%
Interconnected Pre-Timed Signals With Actively Managed Timing	Computer Based Control	8%
Interconnected Pre-Timed Signals Various Types of Master Control and Timing Plans	Optimization of Signal Timing Plans	12%

Reference: (4)

Because signal improvements do reduce travel times and stop and go driving conditions, they also will produce measurable reductions in carbon monoxide (CO) and hydrocarbon (HC) emissions. Although system or region wide air quality benefits are likely to be low, their measurable local benefits to air quality and congestion relief within downtown and other major activity areas warrants their continued implementation.

Traffic Operations

Traffic Operations are similar to signalization improvements in that they primarily are oriented to reducing congestion on local and arterial streets by improving the efficiency of the system. Their benefits to air quality are easier to define at the local level than system-wide.

All traffic operation actions focus on improving the efficiency of the roadway system by reducing delays and stops, and improve air quality by allowing higher travel speeds which lower emissions. Due to the specific nature and variability in applying each of these improvements, consistent data that evaluate all their benefits are minimal, although the results of particular projects are available.

Generally, each action will improve traffic flow and safety. In Boston, reconstruction of several intersections improved level of service considerably. In San Francisco, data compiled for turning restrictions imposed for a series of intersections indicated that accidents were reduced by 40 to 50 percent. In Wichita Kansas, implementation of left turn bays and lanes reduced accidents ranging from 40 to nearly 70 percent and improved intersection capacity from 12 to 20 percent.

These actions are very specific in their nature and usually applied in downtown and other major activity centers. The Boston Back Bay case study provides an assessment of how assembling several of these actions along with signalization improvements and enforcement can provide a powerful traffic operations plan that can fundamentally affect circulation in a relatively large area and result in overall improvements in system travel speed and efficiency.

Traffic operation measures are similar to traffic signal improvements as they essentially relieve congestion and stop and go driving. Their system or region wide benefits to air quality are probably low. However, in conjunction with their proven effectiveness to improve traffic bottlenecks and flow, they likely provide measurable reductions in localized carbon monoxide (CO) and hydrocarbons (HC) emissions.

Enforcement and Management

Enforcement and Management programs provide a variety of tools that standing alone or in combination with other measures such as traffic operations and signalization improvements can provide an additional means to improve traffic flow conditions both locally or at the corridor wide level.

Enforcement

The most effective deterrent to traffic violations is consistent enforcement (usually by police highway patrols) to reinforce the need to comply with proper usage of lanes. A review of before and after case studies involving HOV lane violations clearly indicated a relationship between the level of consistent enforcement and violations. Where regular enforcement of HOV lanes has always been maintained, such as for the North Freeway in Houston and the Shirley Highway in Northern Virginia, violation rates of under 5 percent of total vehicles using the HOV lanes were cited. Where jurisdictional, legal or financial impediments restricted HOV lane enforcement, such as the Southeast Expressway in Boston and I-95 in Miami, violation rates of over 40 percent were observed and the travel time benefits reduced considerably from earlier experiences.

Enforcement of traffic and parking programs to improve local and arterial street mobility also can be critical to the overall success of a traffic management program as shown in Figure 1 for the Back Bay project in Boston. In this example, the application of intense enforcement of parking regulations along a critical arterial roadway resulted in increasing curb-side parking capacity by reducing the number of illegal long-term parking at metered spaces, which resulted in a dramatic reduction in double parking and increasing the arterial capacity enough to reduce travel times by 30 percent, and despite the additional traffic attracted to the arterial by the improvements.

Incident Management Systems

Many levels of sophistication are possible. Though the use of such systems, however, incident duration can be reduced by an average of 10 minutes. A 1986 Federal Highway Administration study revealed that such a system could reduce congestion on approximately 30 percent of the major urban area highway mileage.

Data related to incident-caused congestion is sketchy, although examples do exist. The Los Angeles 42 mile freeway electronic surveillance project produced reductions in delay of 65 percent, and other systems have reported approximately a 50 percent reduction. At another Los Angeles location where incidents are monitored with pavement detectors and closed circuit television cameras, incident management teams are dispatched to clear major incidents. The average duration of lane blockages during incidents has been reduced from 42 minutes to 21 minutes.

The ITE "Toolbox for Alleviating Traffic Congestion" handbook states that 60 percent of all freeway congestion may be caused by non-recurring events such as accidents and breakdowns. The handbook further states that during periods of congestion, an incident management system could decrease travel times by 10 to 45 percent, i.e., for all sections of a highway that are currently congested, approximately 60 percent of these sections

could be upgraded to relatively free-flow conditions through use of a surveillance and management system.

Ramp Metering

Many cities regularly use ramp metering to manage traffic congestion. A survey made for the Federal Highway Administration showed that travel speeds on the highway were increased by nearly 30 percent after installing ramp metering. Even when delays on ramps were included, the average speeds still increased by 20 percent and travel times decreased by 17 percent. Different levels of control have been implemented, from metering to improve one or two specific problem areas to attempting system-wide applications such as in California where Caltrans is developing a Traffic Operations System concept for the Bay Area that would include ramp metering on most of the highway corridors.

Benefits to air quality would obviously be greater with larger-scale metering programs, although there could be increases in localized CO concentrations in the areas of individual ramps if excessive queues develop. In addition, it is important to take into account the excess emissions that may occur during high levels of ramp acceleration in evaluating the air quality benefits of ramp metering. As cited in the ITE "Toolbox for Alleviating Traffic Congestion" handbook, broad application of ramp metering has resulted in significant benefits to regional mobility. The Minnesota Department of Transportation compared conditions on a highway before and after a metering system was installed and found that peak hour speeds increased from 37 to 43 mph. Other locations were cited as experiencing speed increases of 30 percent, while reducing congestion by approximately 60 percent.

Ramp metering is an effective method for improving the efficiency of a highway system. However, many of the case studies indicated that along with travel speed improvements brought about by the ramp metering were measurable increases in traffic volumes, which raises the possibility that metering may induce additional traffic or increase vehicle miles of travel (VMT). Several studies have concluded that this additional traffic was primarily attracted from other roadways. However, no detailed surveys have been conducted to determine whether the additional traffic also includes shifts from other modes. Where large-scale metering is implemented and resulted in substantial improvements to travel speed, it is likely that some percentage of any additional traffic or VMT detected would reflect a shift from another mode of travel. This would at least partially offset any air quality improvements generated by faster, more consistent travel speeds on the highway system.

■ Program Costs

The cost to implement traffic flow improvements ranges considerably as summarized in Table 3. Strategies involving right-of-way acquisition or construction have relatively

Table 3. Representative Traffic Flow Strategy Costs

	Capital Costs
Traffic Signalization	
Equipment or software updating	\$2,000-\$10,000/Signal
Timing plan improvements	\$300-\$400/Signal*
Signal coordination and interconnection	\$5,000-\$13,000/Signal
Signal removal	\$300-\$400/Signal*
Traffic Operations	
Converting two-way streets to one-way	\$500-\$2,000/Block
Two-way street left turn restrictions	\$400/Intersection
Continuous median strip for left turn lanes	\$2,000/Block
Channelized roadway and intersections	\$200-\$500/Block or Inters.
Roadway and intersection reconstruction	Widely varying
Enforcement and Management	
Enforcement for HOV Lane Facility	\$70,000-\$100,000/Year*
Enforcement for Downtown Management Plan	\$500,000-\$1,000,000/Year*
Incident Management Systems	\$1,000,000/Mile
Ramp metering	\$50,000/Ramp

* Operating, Maintenance or Labor Cost Only

high capital costs. Other actions involving local traffic operations or signal improvement can be implemented at low cost. The following sections provide an overall comparative summary of the level of funding that each type of action may require to implement.

Traffic Signalization

Traffic Signalization costs may vary greatly depending on the type of improvement and number of signals effected. Representative signal improvement costs are shown on Table 3 for four basic type of changes. Updating a specific signalized intersection with a new traffic controller or traffic control software strategy can cost from \$2,000 to \$10,000 per location. Timing plan improvements would require a data collection effort to identify new signal timings and subsequent re-timing of signals at each location, with labor costs ranging from \$300 to \$400 for each signalized intersection. Signal coordination and interconnection would allow "hard wired" connection of traffic signals to ensure that each location may be part of a system-wired traffic control strategy managed by a series of controllers or by a centralized computer-based master control system. Costs vary from about \$5,000 per intersection, when only cable installation is required to connect each intersection, to \$13,000 per intersection, when cable and controller installation is needed. Signal removal would require field survey to substantiate the elimination of signals and field work to remove the equipment. This would involve labor costs of approximately \$300 to \$400 per location.

The costs shown in Table 3 represent unit costs, or the cost to implement signal changes for one location or intersection. A signal improvement project sufficiently large enough to generate significant improvements to area mobility and air quality would involve a large number of signals. For example, the timing optimization program for Downtown Sacramento involved over 200 locations and cost about \$100,000. A new computerized traffic signal control system involving 300 intersections in downtown Boston and including several new timing strategies, interconnection, and controller timing is estimated to cost about \$4,000,000.

Traffic Operations

Traffic Operation improvements include a wide array of actions with varying costs, although they typically are inexpensive when compared to actions such as construction of new lanes. Converting streets to one-way operation or implementing left turn restrictions at intersections involves installation of new signage and possibly removing or relocating existing signs and traffic signals at costs that range from \$400 to \$2,000 per block. Implementing a continuous left turn median lane requires new signage and lane markings, and modifications to existing signage and signals. Costs are estimated at \$2,000 per block, assuming that a sufficient right-of-way exists to avoid any roadway widenings. Improving the channelization of a roadway or intersection with pavement

striping, markings and signage would cost about \$200 to \$500 for each block or intersection. Roadway and intersection reconstruction can be very expensive in urban or downtown areas if additional right-of-way is required or construction involves many utility relocations.

Systemwide traffic operation improvements that involve many sites can result in significant costs to implement. The Back Bay Transportation Study in Boston developed a program of non-signal traffic improvements that included dozens of intersections, with actions that included peak period turning restrictions on the area's major arterials, street reversals, parking restrictions, left turn bays, new channelization layouts and reconstruction of several major intersections to improve circulation and safety. Most of these actions were inexpensive, with reconstruction of intersections, at \$100,000 to \$200,000 per location, clearly reflecting the highest cost of these actions. The total cost of this program was estimated at over \$6,000,000.

Enforcement and Management

Enforcement and Management reflect actions that include equipment and capital costs, or operating and maintenance costs. A facility enforcement program includes the labor costs associated with traffic control officers providing patrols and surveillance of the facility during its operation. A cost of \$70,000 to \$100,000 to enforce one HOV lane facility per year reflects the level of enforcement in place in such areas as Houston and Northern Virginia where HOV lane violation rates are below 5 percent. A traffic and parking enforcement program that includes meter maids, uniformed police officers and tow trucks to cover several major and minor arterials within a downtown can cost from \$0.5 to over \$1.0 million per year. However, the revenue generated by the fines issued as part of an enforcement program generally exceed costs by a factor of at least seven or eight.

An **incident management system** that consists of such sophisticated elements as embedded traffic detectors, changeable message signs, closed circuit television and some type of central computer control will cost about \$1,000,000 per mile to implement. This estimate is largely based on the electronic surveillance project that was implemented in Los Angeles. The Minuteman program in the Chicago Metropolitan area is reported to cost \$5.5 million per year but saves motorists an estimated 9.5 million vehicle-hours of delay at a value of \$95 million per year. **Ramp metering** costs about \$50,000 per ramp; a highway corridor system ramp metering would cost over \$1,000,000.

■ Implementation Considerations

This discussion of traffic flow improvement strategies has focused primarily on potential transportation and air quality related benefits that such actions would provide.

However, despite their positive impact for improving the effectiveness of a transportation system, a number of institutional issues can obstruct the implementation of most of these actions. For any improvement to be successful, good coordination needs to exist between state and local traffic agencies and with the police department having enforcement responsibilities.

Traffic Signalization and Traffic Operation improvements typically are implemented by city and county public works departments, with financial assistance usually provided from State and Federal funding sources. Since these actions facilitate urban driving, they usually generate little public opposition, with the exception that project abutters may object to the disruption caused by construction and to such actions as street reversals. Important factors, therefore, that should be considered to minimize potential objections and facilitate implementation include the following:

- Many small jurisdictions and even some large central cities have limited traffic engineering capabilities and budgets. In these cases, traffic signal management and roadway maintenance and design is often limited to the most basic or rudimentary installation and maintenance functions.
- State Departments of Transportation have a strong influence over the allocation of federal roadway aid funds. Many states have priorities that stress high-capital road and bridge building, and that do not include traffic operations and signal control systems.
- Traffic operation improvements require a public planning process to generate local support for the actions. The potential impacts of each strategy must be identified and clearly communicated. The potential benefits and costs must be clearly articulated. For example, for a proposed turning restriction, the amount of traffic to be diverted and the potential alternative travel paths to be taken must be considered and reviewed with the public. For the planned reconstruction of an intersection, construction schedules must be developed and reviewed by those who will be directly impacted by the project to reduce their concerns and possible opposition.

Enforcement and Management strategies typically involve a substantial amount of time and planning to implement. Following are several key factors that need to be considered for enforcement programs:

- Enforcement is probably the most important factor necessary to ensure success for all the other actions considered in this chapter.
- Heavy enforcement must be part of the early stages of a project to reinforce the need for changes in attitude and behavior. Given this effort early-on, the level of enforcement can be reduced later.
- The design of a project should provide for self-enforcement. For an HOV lane, for example, physical barriers clearly prevent casual violations.

- A successful enforcement program includes a suitably structured system of fines that serve as a deterrent in itself. Relatively low fines do little to support other elements of an enforcement program. Analogously, very high fines may not be considered acceptable by the majority of users and foster public resentment of the program.

Implementation of Highway Information Management Systems and Ramp Metering may take a number of years. The typical schedule from conceptual planning to a completed system may require 5 to 10 years.

The planning phase for such systems must include participation from local officials and foster the cooperation of the media to educate the public in the uses and desirability for such a system. For a ramp metering system, detailed planning must demonstrate that overall improvements to the regional freeway system are not attained by deteriorating mobility on local arterials, caused by motorists who may choose to by-pass those ramps.

Incident management programs are often beset by organizational and institutional problems in the implementation phase. Incident management has become a metropolitan area problem affecting a multitude of organizations, often with overlapping jurisdictions. Above all, a commitment is needed to address the problem and take advantage of the knowledge, skills and technology that exist to implement an effective incident management program.

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