

**2009 URBAN MOBILITY REPORT:**  
**Six Congestion Reduction Strategies and Their**  
**Effects on Mobility**

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## SUMMARY

The Urban Mobility Report (1) procedures provide estimates of mobility at the areawide level. The approach that is used describes congestion in consistent ways using generally available data allowing for comparisons across urban areas or groups of urban areas. Past procedures only looked at projects that added lanes or reduced demand and overlooked many other types of projects that affected the demand characteristics. This report extends the procedures to several other treatments and even to public transportation. The goal is to include all improvements, but good data is necessary to accomplish this.

This report describes a framework for incorporating additional treatments and shows effects of those treatments. These two pieces should be viewed separately. This is an attempt at showing the benefits of such projects and programs at an areawide level. The methodology for analyzing the treatments is developing just as transportation systems are also in a constant growth and development cycle. The results from the analysis could easily change as the research proceeds in this area.

The effect of operational treatments can be viewed as proportional to:

- the area of coverage
- the density of that coverage
- the mobility improvement provided by the treatment.

The traditional UMR procedures used to estimate travel delay can be modified by these factors to estimate new values that more accurately reflect the mobility contributions of the treatments. High-occupancy vehicle lanes and public transportation service have not been included in previous mobility estimates, and the operating and ridership statistics can be added to the database for each area.

The area and density factors have been estimated from federal, state and local databases and some confirmation of this information has been obtained by local reviews. The delay reduction effect of the treatments described below has been tailored as much as possible to the local implementation of the treatment, but typically varies with congestion level.

1. **Ramp Metering** – Improves the ability of the freeway to maintain relatively high speeds under conditions of high demand and postpones the onset of congestion.
  - **Inputs** to the delay reduction calculations range from 0 to about a 12 percent reduction.
  - **Results** show that ramp metering reduced freeway delay by about 3 percent in the 25 areas with metering in use.
2. **Traffic Signal Coordination**—Traffic signal coordination programs reduce delay by allowing more vehicles to maintain a smooth flow—particularly in the peak direction.
  - **Inputs** to the delay reduction calculations ranged from less than 1 percent to about a 6 percent reduction.
  - **Results** show that signal coordination reduced arterial delay by about 1 percent in the 90 areas studied.

3. **Incident Management Programs**—Quickly detecting and removing crashes and vehicle breakdowns reduces delay by returning traffic capacity to normal levels.
  - **Inputs** to the delay reduction calculations ranged from 0 to about a 40 percent reduction of incident delay.
  - **Results** show that incident management reduced freeway delay by just under 8 percent in the 79 areas that had some form of incident management implemented.
4. **Arterial Street Access Management**—Providing smooth traffic flow and reducing collisions is the goal of a variety of individual treatments that make up an access management program.
  - **Inputs** to the delay reduction calculations ranged from 0 to 15 percent increase in recurring delay and 12 to 22 percent decrease in incident delay.
  - **Results** show that access management reduced arterial delay by about 3 percent in the 90 areas included in the study.
5. **HOV Lanes**—Providing reliable high-speed travel improves mobility levels in the corridors where HOV service is available. The HOV travel volume and speed statistics have been added to the current roadway system database for each area to produce an areawide reduction effect on the Travel Time Index.
  - **Inputs** to the delay reduction calculation for HOV lanes included 16 urban areas with HOV data with an average daily ridership of about 1,293,000 daily passenger-miles of travel.
  - **Results** of the HOV analysis showed that the Travel Time Index dropped by almost 2 points, on average, in each of the 16 areas with HOV lanes.
6. **Public Transportation Service**—Including public transportation service in a mobility measure will be accomplished with one of two methods. One method is to include the percentage of on-time transit riders in the uncongested roadway travel categories. The other approach would be to transfer transit riders into private automobiles and recalculate the mobility measures to estimate the increased congestion levels.
  - **Inputs** to the delay reduction calculation for public transportation included data for all 90 urban areas with an average annual ridership of approximately 553 million passenger-miles of travel.
  - **Results** using the first method (all transit riders are placed in uncongested auto trips) showed the Travel Time Index, on average, was reduced by approximately 2 points in the 90 urban areas studied.
  - **Results** using the second method (transit riders are placed in autos and mixed in with existing traffic) showed that transit riders added a total of 630 million hours of delay in the 90 urban areas in 2007. This additional delay could be viewed as the delay savings associated with the existence of transit in these areas.

## BASIC DATA SOURCES

The Urban Mobility Report speed, delay and performance measure estimation methodology consists of two elements – use of **directly collected data** to study specific issues in depth where possible and **estimation processes** for other studies based on several national sources and analysis products:

- ITS Deployment Tracking Survey (IDTS)—This database provides access to information on the deployment and integration of ITS technology gathered through a series of nationwide surveys, beginning in 1996 and continuing to 2002
- ITS Deployment Analysis System (IDAS)—IDAS is a modeling tool that enables the user to conduct systematic assessments and quantitative evaluations of the relative benefits and costs of more than 60 types of ITS investments, in combination or in isolation
- Highway Performance Monitoring System (HPMS)—HPMS is a national level highway information system that includes data on the extent, condition, performance, use, and operating characteristics of the Nation’s highways.
- Highway Economic Requirements System (HERS)—HERS is an engineering/economic analysis (EEA) tool that uses engineering standards to identify highway deficiencies, and then applies economic criteria to select the most cost-effective mix of improvements for system-wide implementation.
- Public Transportation Operation Statistics (APTA)—The American Public Transportation Association produces an annual report detailing transit usage by the various transit agencies within each urban areas across the U.S.
- Other data sources

## ALTERNATIVES TO ESTIMATION PROCEDURES

In a perfect world, there would be no need for estimates of the effects of mobility enhancing projects as the data could be directly collected from the transportation system itself. However, the data collection for such projects is often cumbersome and expensive to collect and for these reasons—often goes uncollected.

Often, before/after studies or corridor analyses are performed to analyze the effects of an improvement by comparing characteristics before and after implementation. At other times, simulation models are used to calculate the benefits. Many of these types of analyses do exist for operational treatments but are typically performed over small areas such as a few miles of a road or perhaps an entire corridor.

Since this research effort focuses on regional transportation systems, some estimation is necessary as most areas do not perform system-wide studies. The information gained from the directly collected data and other detailed studies can be used to generate the necessary estimating parameters, but the data that will be available in most areas are the inventory and use statistics.



## **INCLUDING DIRECTLY COLLECTED DATA**

The Mobility Monitoring Program (7) funded by FHWA has allowed the Texas Transportation Institute and Cambridge Systematics to identify and help create several data archives for the freeways that are monitored in 29 urban areas for 2003. The data can be used to study the effects of a variety of treatments, as well as examine congestion and reliability levels and trends over several years when those data are available.

Other sources of directly collected data might include special project-focused studies or periodic speed or travel time studies. These studies support the estimation processes and studies of particular elements of the transportation system, and that may continue to be their role. Additional information will be gathered concerning the before and after conditions and the level of congestion in the area of the treatment (because some treatments have more effect in congested areas) to extend the usefulness of this data.

The directly collected data used in the Urban Mobility Report will include archived data information from the urban traffic operations centers or statewide data efforts such as California's Performance Measurement System (PeMS) (8). The information will also include studies of individual projects such as HOV lanes, ramp meters, incident management programs where that information is collected with sufficient level of detail and attention to isolating the before/after effects.

## **CONCEPT DESCRIPTION**

The effect of operational treatments is proportional to the area of coverage, the density of that coverage and the mobility improvement provided by the treatment. The procedures used to estimate travel delay can be modified by these factors to estimate new values that more accurately reflect the mobility contributions of the treatments. High-occupancy vehicle lanes and public transportation service have not been included in previous mobility estimates, and the operating and ridership statistics from those elements can be added to the database for each area.

Three factors are key to estimating the mobility effects of operational treatments:

1. Area covered by the treatment—how much of the system has the treatment?
2. Density of the treatment within the covered area (particularly as it applies to service patrol programs)—how often is the area patrolled, updated or viewed?
3. Delay reduction effect—how much effect does the treatment have?

The area and density factors can be estimated from HPMS and IDTS databases and confirmed by local reviews. The delay reduction effect will be tailored as much as possible to the local area implementation of the treatment. State and local transportation staff can review the delay reduction factors to ensure reasonableness.

The ITS Deployment Tracking Survey (IDTS) database will be used when specific project effect information is not available or may be used to supplement specific project information. The general method used in these cases is described for each treatment type in that particular section.

The ITS Deployment Analysis System (IDAS) contains the tracking information and methods used by the U.S. Department of Transportation to evaluate ITS systems nationally.

## **FREEWAY ENTRANCE RAMP METERING**

### *What Does Ramp Metering Do?*

Ramp meters are modified traffic signals placed on the entrance ramps of urban freeways. They may operate on a pre-timed cycle or be responsive to conditions on the freeway mainlanes. Ramp meters typically release one vehicle per cycle from the ramp. The goal of these signals is to smooth out the flow of vehicles entering the freeway. Groups of vehicles entering a freeway that is approaching capacity can cause the freeway demand to exceed capacity. Stop and go traffic, reduced volume, and increased accident potential are associated with traffic demand exceeding capacity. If vehicles enter the freeway at a uniform rate, however, the smooth flow of traffic on the freeway can be preserved longer. Ramp meters will not eliminate congestion in most cases, but may delay stop-and-go conditions for 15 to 30 minutes having significant benefits.

### *Estimating the Delay Reduction Effect*

Freeway entrance ramp metering improves the ability of the freeway mainlanes to maintain relatively high speeds under conditions of high demand. Postponing the onset of congestion can significantly improve the average travel speeds over the peak period. If the waiting time on the entrance ramps is factored into the estimates, the travel time savings are reduced, but not eliminated. Also included in the savings is the delay that can be reduced from a lower accident rate.

The IDTS includes information on the miles of system that was metered in 2002. The information from the HERS Operations Preprocessor (9) incorporates results from the Minnesota Ramp Metering Study (10). The Twin Cities study concluded that there was a 3 percent reduction in recurring delay reported for freeway, entrance ramp and street system and a 7 percent reduction reported for freeways-only. The recurring delay benefits will translate into some reduction in incident delay based on the current UMR methodology that factors incident delay from recurring delay. Exhibit 1 identifies the total delay reduction effect by freeway congestion category.

**Exhibit 1. Ramp Metering Benefits in Delay Reduction (HPMS and Deployment Tracking)**

<b>Ramp Meter Strategy</b>	<b>Congestion Level</b>				
	<b>Uncongested</b>	<b>Moderate<sup>1</sup></b>	<b>Heavy<sup>1</sup></b>	<b>Severe<sup>1</sup></b>	<b>Extreme<sup>1</sup></b>
No ramp meters	0	0	0	0	0
Isolated , pre-timed, centrally controlled or traffic responsive (recurring/incident)	0	peak=0 off-peak=0	peak=5.6 off-pk=0	peak=11.0 off-peak=7.3	peak=12.4 off-peak=11.6

<sup>1</sup> Derived from an equation relating speed to delay reduction for each congestion level.

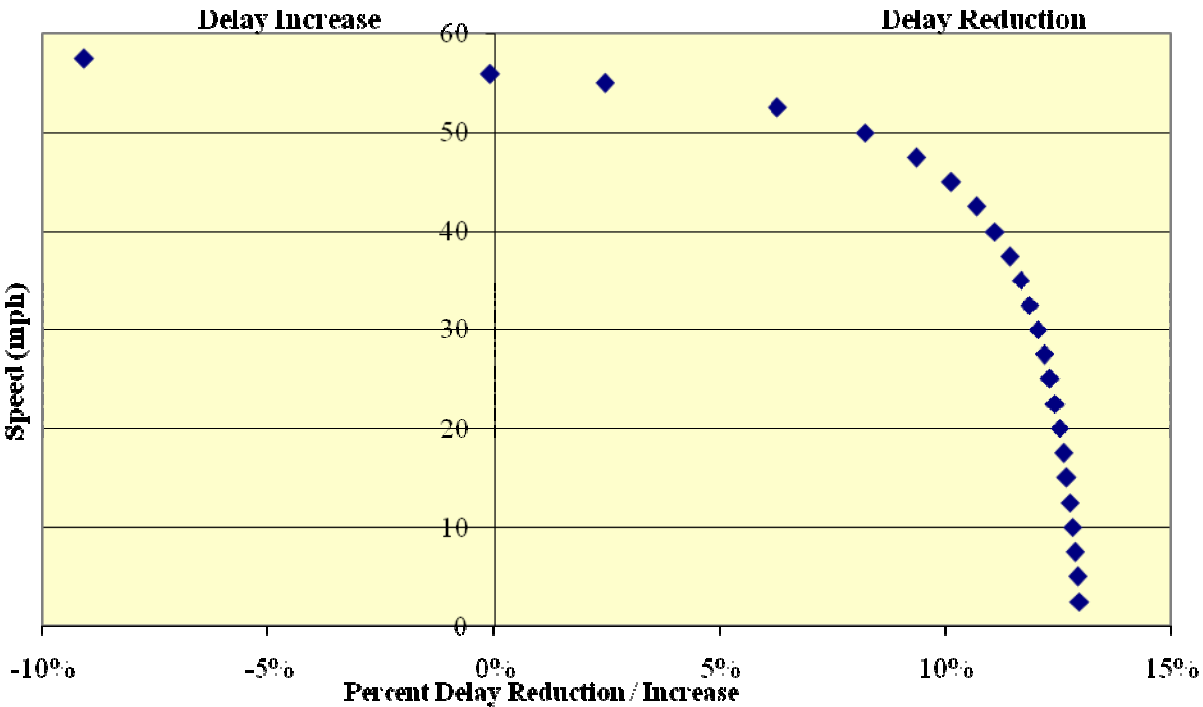
Source: HERS Operations Preprocessor (9), Minnesota Ramp Metering Study (10), and TTI Analysis

*Urban Mobility Report Procedures*

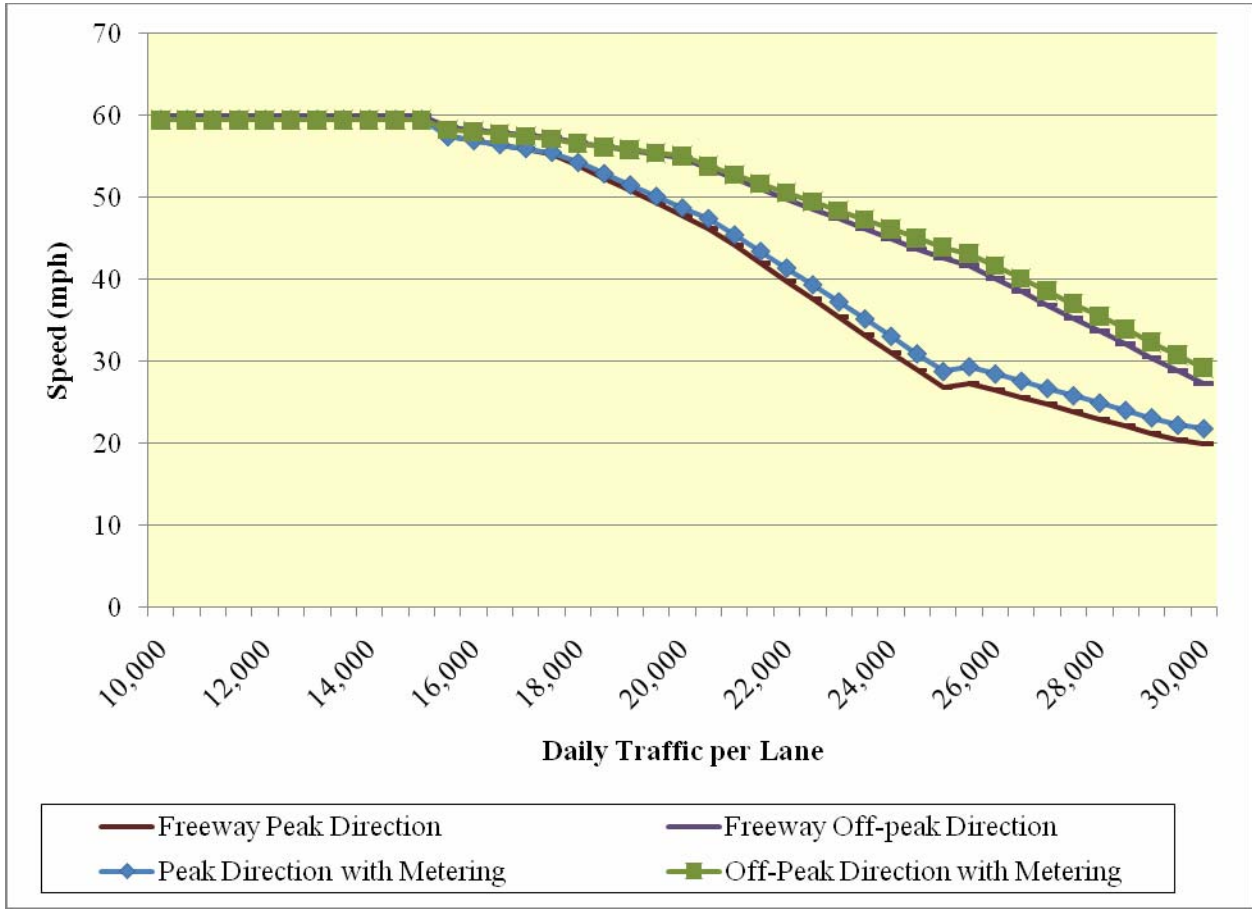
Several steps are applied to the HPMS Universe sections for each urban area (the section of the database with volume and number of lanes for each section of the road system in the U.S.). The congestion level is determined for each section of roadway using the ADT per lane. The directional factor is applied to estimate the peak and off-peak traffic volume. The section of roadway is labeled as metered or unmetered based on the HPMS data. The average delay savings are calculated using the delay reduction percentages shown in Exhibit 1 for each congestion level. These percentages are based on the relationship in Exhibit 2 that is derived from the HERS model.

As an example of how the delay reduction factor relates to changes in average speed, Exhibit 3 shows the two freeway speed curves for peak and off-peak directions under the base UMR methodology, and the speed curves associated with ramp metering for both peak and off-peak travel. The delay reduction effects of ramp metering are more significant at the onset of congestion. Moving the congested time period back by only 15 to 30 minutes can have significant benefits. Ramp metering was found to be less effective after the onset of congestion, and the revised Minnesota metering scheme illustrates this.

**Exhibit 2. Ramp Metering Effects  
Speed versus Percent Delay Savings**



**Exhibit 3. Freeway Speed Curves**



*Estimated Delay Reduction*

**Effect of Ramp Metering in 25 Areas Where Implemented**

Exhibit 4 displays the amount of travel and the miles of freeway that are covered by ramp metering in the 25 urban areas that had ramp metering.

**Exhibit 4. Freeway Ramp Metering Inventory - 25 Areas**

Population Group	Average Covered Freeway Travel		Average Covered Freeway Lane-miles	
	Daily VMT (000)	Percentage	Miles	Percentage
Very Large (12)	19,670	34	869	28
Large (10)	12,177	60	619	54
Medium (3)	2,173	39	151	35
Small (0)	0	0	0	0
25 Area Average	14,573	40	683	35
25 Area Total	364,334	40	17,069	35

Source: HPMS (4), IDTS (2), and TIT Analysis

The effects of ramp metering in the 25 urban areas are shown in Exhibit 5. In these areas, about 364 million daily vehicle-miles of travel (40 percent of all freeway travel in the 25 areas) occurred on 17,069 lane-miles of freeway (35 percent of all freeway miles in the 25 areas) containing ramp metering. Some of the effects include:

- Overall, ramp metering lowered the freeway TTI by 0.012 (2.7 percent) and reduced the total freeway delay by 40 million hours (2.8 percent) in the 25 urban areas having ramp metering.
- The largest point and percentage reductions in freeway TTI and delay occurred in the Very Large urban areas with a 0.012 point reduction (2.4 percent) in the TTI and in the Large urban areas with a 8.9 million hour reduction (3.7 percent) in total hours of delay.
- There was no ramp metering reported in the Small urban areas.

**Exhibit 5. Freeway Ramp Metering Effects - 25 Areas**

Population Group	Freeway Travel Time Index			Freeway Hours of Delay (million)		
	Base	With Ramp Metering	Reduction	Base	With Ramp Metering	Reduction
Very Large (12)	1.491	1.479	.012	1,174.0	1,143.2	30.8
Large (10)	1.346	1.335	.011	239.0	230.1	8.9
Medium (3)	1.098	1.098	.000	5.9	5.8	0.1
Small (0)	—	—	—	—	—	—
25 Area Average	1.452	1.440	.012	1,418.9	1,379.2	39.8

Source: TTI Analysis

### Effects of Ramp Metering in All 85 Areas

This section of analysis looks at the effects of ramp metering as it relates to all 90 of the areas in the UMR. Exhibit 6 displays the amount of travel and the miles of freeway that are covered by ramp metering in the 90 urban areas.

**Exhibit 6. Freeway Ramp Metering Inventory - 90 Areas**

Population Group	Average Covered Freeway Travel		Average Covered Freeway Lane-miles	
	Daily VMT (000)	Percentage	Miles	Percentage
Very Large (14)	16,860	31	745	25
Large (29)	4,199	26	213	20
Medium (31)	210	3	15	3
Small (16)	0	0	0	0
90 Area Average	4,048	25	190	19
90 Area Total	364,334	25	17,069	19

Source: HPMS (4), IDTS (2), and TIT Analysis

The effects of ramp metering in the 90 urban areas are shown in Exhibit 7. In these areas, over 364 million daily vehicle-miles of travel (25 percent of all freeway travel in the 90 areas) occurred on 17,069 lane-miles of freeway (19 percent of all freeway miles in the 90 areas) containing ramp metering. Some of the effects include:

- Overall, ramp metering lowered the freeway TTI by 0.008 (2.3 percent) and reduced the total freeway delay by 40 million hours (2.2 percent) in the 90 urban areas.
- The largest point reduction in freeway TTI occurred in the Very Large urban areas with a 0.011 point reduction (2.3 percent). The delay was reduced by 30.8 million hours (2.4 percent) in the 14 areas.

**Exhibit 7. Freeway Ramp Metering Effects - 90 Areas**

Population Group	Freeway Travel Time Index			Freeway Hours of Delay (million)		
	Base	With Ramp Metering	Reduction	Base	With Ramp Metering	Reduction
Very Large (14)	1.479	1.468	.011	1,284.4	1,253.7	30.8
Large (29)	1.254	1.249	.005	424.9	416.0	8.9
Medium (31)	1.121	1.121	.000	90.0	89.9	0.1
Small (16)	1.049	1.049	.000	7.4	7.4	0.0
90 Area Average	1.347	1.339	.008	1,806.8	1,767.0	39.8

Source: TTI Analysis

## TRAFFIC SIGNAL COORDINATION

### *What Does Traffic Signal Coordination Do?*

Traffic signals can provide for the orderly movement of traffic, increase the capacity of intersections, and reduce the frequency of accidents. Making improvements to traffic signals can be one of the most cost-effective tools to increase mobility on arterials. In many cases, traffic signal equipment can be updated to more modern equipment to allow for greater flexibility of timing plans, including coordination with other nearby signals for progression. In some cases, existing equipment may be adequate, however, due to changing traffic patterns, timing plan improvements may be needed to more efficiently handle current traffic flows.

### *Estimating the Delay Reduction Effect*

Traffic signal coordination programs reduce delay on arterial streets by allowing more vehicles to maintain a smooth flow—particularly in the peak direction. The IDTS dataset includes information about the total number of traffic signals managed by the reporting agency and the number of signals controlled from a central location. The HERS model estimates a maximum delay effect of about 9% reduction in recurring delay, based on the set of speed curves in IDAS for improvements in technology. These range from reductions of 3% for actuated signal control, 9% for centrally controlled systems and closed-loop systems and 20% for real-time adaptive signal controls. It might not be reasonable, however, to assume both directions at major crossing streets get a 9% benefit, and the values in Exhibit 8 have been reduced for network relationships.

### Exhibit 8. Signal Coordination Benefits in Delay Reduction

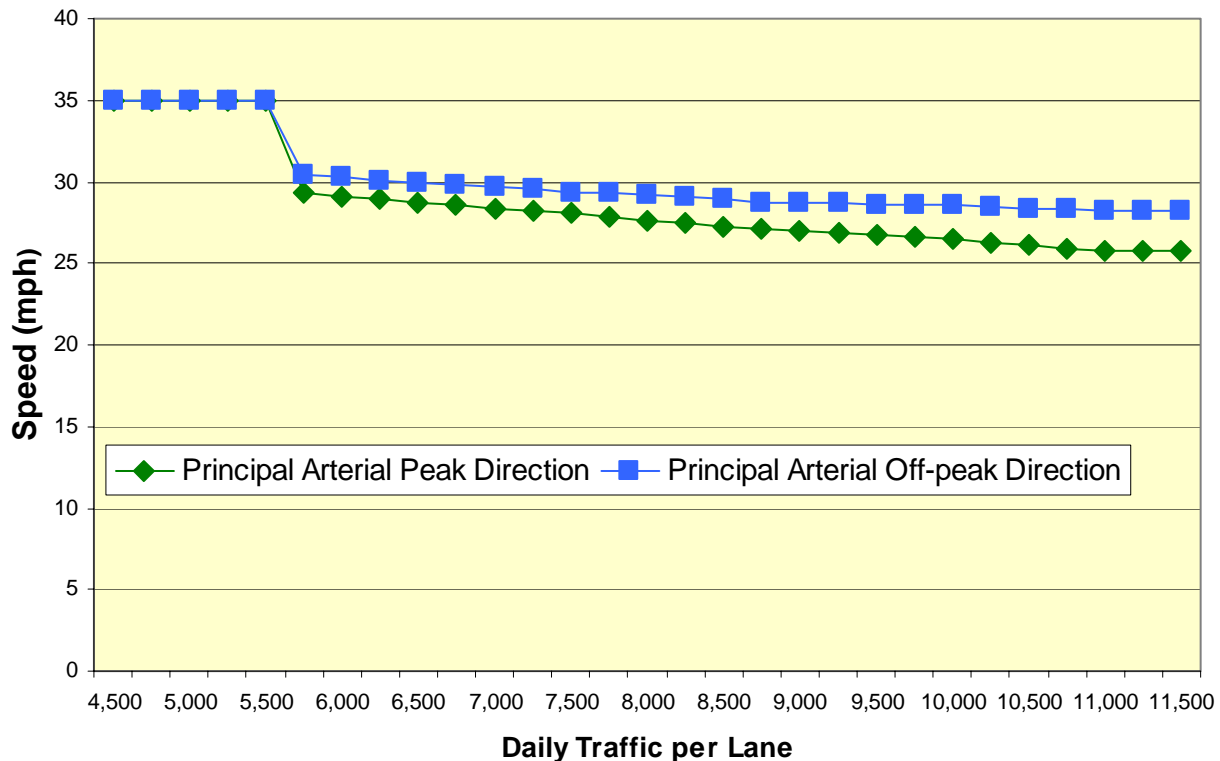
Signal Strategy	Signal Density (signals per mile)	Congestion Level				
		Uncongested	Moderate	Heavy	Severe	Extreme
No coordination	--	0	0	0	0	0
Traffic Actuated	Less than 3 per mile	0	0.5	0.5	0.5	0.3
	3 to 6 per mile	0	2.2	2.1	1.9	1.5
	More than 6 per mile	0	2.1	2.1	1.5	1.1
Progressive (centralized or real-time)	Less than 3 per mile	0	1.0	1.0	0.9	0.7
	3 to 6 per mile	0	5.0	4.8	4.5	3.6
	More than 6 per mile	0	6.1	6.0	4.6	3.1

Source: HERS (9) and TTI Analysis

### Urban Mobility Report Procedures

Several steps are applied to the HPMS sample sections for each urban area. The congestion level for each section is determined by using the ADT per lane for each section. Directional factors are applied to separate the traffic into peak and off-peak volumes. The signal density and type of signals are determined for each of the sections of roadway. The average speed for each congestion level is calculated once all of the sections of roadway are assigned (Exhibit 9). Finally, the average delay savings are calculated using the delay reduction percentages shown in Exhibit 6. This is accomplished by applying the appropriate reduction percentage for each congestion level, signal strategy and signal density to the delay that was calculated for each of those combinations in the preceding step.

### Exhibit 9. Principal Arterial Speed Estimation



## Estimated Delay Reduction

### Effects of Signal Coordination in All 85 Areas

All 90 urban areas had signal systems in place so there are not two analyses of the inventory and effects of signal systems. Exhibit 10 displays the vehicle-miles of travel and lane-miles of principal arterial streets that had either actuated or progressive signal systems. In the 90 urban areas studied, over 855 million daily vehicle-miles of travel (60 percent) occurred on about 153,654 lane-miles of principal arterial streets (57 percent) that have either actuated or progressive signals in place.

**Exhibit 10. Principal Arterial Signal Coordination Inventory**

Population Group	Average Covered P.A.S. Travel		Average Covered P.A.S. Lane-miles	
	Daily VMT (000)	Percentage	Lane-miles	Percentage
Very Large (14)	33,295	63	5,985	63
Large (29)	11,252	57	1,517	55
Medium (31)	3,688	55	640	46
Small (16)	1,937	51	378	49
90 Area Average	9,496	60	1,707	57
90 Area Total	854613	60	153,654	57

Source: HPMS (4), IDTS (2), and TTI Analysis

Overall, principal arterial signal coordination reduced the arterial TTI by 0.003 (1.1 percent) and reduced the arterial hours of delay by 16.2 million hours (0.8 percent). Some of the results of signal coordination include (Exhibit 11):

- The greatest point reduction in the arterial TTI occurred in the Very Large urban areas with a 0.004 reduction. This equated to a 1.2 percent reduction in the Very Large urban areas.
- The largest savings in delay also occurred in the Very Large urban areas with 10.3 million hours of delay (0.8 percent). The Large urban areas experienced a delay savings of 4.1 million hours (0.7 percent reduction).
- The smallest reduction occurred in the Small urban areas with a 0.001 reduction (1.2 percent) in the TTI and 0.3 million hours of delay savings (0.7 percent).



### Exhibit 11. Principal Arterial Signal Coordination Effects

Population Group	Principal Arterial Travel Time Index			Principal Arterial Hours of Delay (million)		
	Base	with Signal Coordination	Reduction	Base	With Signal Coordination	Reduction
Very Large (14)	1.324	1.320	0.004	1268.0	1,257.7	10.3
Large (29)	1.242	1.240	0.002	559.0	554.9	4.1
Medium (31)	1.168	1.166	0.002	200.0	198.5	1.5
Small (16)	1.140	1.139	0.001	49.4	49.1	0.3
90 Area Average	1.269	1.266	0.003	2,076.3	2,060.1	16.2

Source: TTI Analysis

## INCIDENT MANAGEMENT PROGRAMS

### *What does Incident Management do?*

Approximately half of the delay experienced by travelers in the United States is due to causes other than simple high volume of traffic. This nonrecurring congestion occurs as the result of traffic accidents, stalled vehicles, spilled loads, maintenance/construction activities, special events, and weather. The California DOT estimates that for each minute an incident blocks a lane, approximately five minutes are added to the total time the freeway will be congested. The actual capacity reduction of an incident blocking a lane is greater than the physical reduction in capacity due to motorist “rubbernecking” – slowing down to look at the incident – often on both roadway directions. Although a one-lane blockage out of three lanes translates to a 33 percent reduction in physical capacity, studies have shown an incident blocking a single lane out of three lanes results in a capacity reduction of up to 48 percent. Similarly, a two-lane blockage can reduce the capacity of a three-lane section by as much as 79 percent (1).

One method of combating congestion from nonrecurring incidents is to implement an incident management system. Incident management is a coordinated and planned approach for restoring freeway capacity as quickly as possible after an incident has occurred. The major elements of an incident management system are: detection and verification, response, clearance, and motorist notification.

### *Estimating the Delay Reduction Effect*

Quickly identifying and removing crashes and vehicle breakdowns reduces delay by returning traffic capacity to normal levels. This analysis seeks to estimate where the freeway is monitored or patrolled and how frequently a service vehicle might patrol past the scene of a crash or breakdown. These factors have been studied in some projects, but the most comprehensive estimates of the effects are from the HERS applications. The results from the HERS and other studies are difficult to compare.

The IDTS database lists the amount of roadway covered by detection algorithms, cameras or service patrol vehicles and the number of vehicles used in the motorist assistance efforts. The effects are combined – the detection algorithms allow quicker identification of a problem, the cameras verify the problem and allow for more appropriate and quicker response, and the service

patrols respond and remove the incident. The IDTS does not, however, identify specific sections of treatment.

The HPMS database identifies the specific sections (and miles) covered by each technique. Cambridge Systematics has merged these two elements for the HERS analysis and applied any “remaining miles” in the Deployment estimate to the most congested, but uncovered sections in the HPMS database. The algorithm and camera coverage is coded for the sections of treated road. A density level of 1 service patrol vehicle for every 10 or fewer miles identifies the standard for urban areas that should get a 100% density factor in the delay reduction estimates.

The delay reduction percentages, however, are not as easily translated from the HERS model to the Urban Mobility Study methodology. HERS estimates the effect of service patrols as a 25% reduction in incident duration which, when modeled at the section level with HPMS data resulted in a 65% reduction in incident delay. The camera systems contributed an additional four to five percent reduction in incident duration. When both treatments are combined, this would suggest a 30% reduction in incident duration and an 70 to 75 percent reduction in incident delay. This is too high to use for an areawide average, judging from the Buffer Time Index values in the 2001 and 2002 Mobility Monitoring Project reports and the incident management programs in the study urban areas. The net reduction in delay would seem to be less than the 65% value estimated in the model. The study will continue to compare the two analytical techniques (MMP and HERS). For methodology purposes, the UMR database was examined with a 15% reduction in duration and a 40% reduction in delay if both components are present (see Exhibits 12 and 13).

**Exhibit 12. Incident Delay Reduction Benefits of Freeway Service Patrols (HPMS and Deployment Tracking)**

System Coverage	Patrol Cycle (miles each vehicle covers)	Congestion Level				
		Uncongested	Moderate	Heavy	Severe	Extreme
No patrols		0	0	0	0	0
If 100% of the system is covered	More than 10 miles	0	18	21	24	28
	Less than 10 miles	0	25	28	31	35

Source: HERS (9) and TTI Analysis

**Exhibit 13. Incident Delay Reduction Benefits of Surveillance Cameras (HPMS and Deployment Tracking)**

System Coverage	Congestion Level				
	Uncongested	Moderate	Heavy	Severe	Extreme
No cameras	0	0	0	0	0
Coverage amount					
25%	0	2.5	3.0	3.5	3.5
50%	0	2.5	3.0	3.5	4.0
75%	0	3.0	3.5	4.0	4.5
100%	0	3.0	3.5	4.0	5.0

Source: HERS (9) and TTI Analysis

*Urban Mobility Report Procedures*

Several steps are applied to the HPMS universe sections for each urban area. The congestion level for each section is determined by using the ADT per lane for each section. Directional factors are applied to separate the traffic into peak and off-peak volumes. The existence of freeway service patrols and camera surveillance on each section is determined. The average delay is calculated for each congestion level and the corresponding savings are calculated using the delay reduction percentages shown in Exhibits 12 and 13. This is accomplished by applying the appropriate reduction percentage for each congestion level and treatment type to the delay that was calculated for each of those combinations.

*Estimated Delay Reduction*

**Effects of Incident Management in 79 Areas Where Implemented**

Incident Management programs were in place in 79 of the 90 urban areas. Exhibit 14 shows that over 713 million daily vehicle-miles of travel (50 percent) occurred on 37,732 lane-miles of roadway (44 percent) that were monitored with some form of camera surveillance in 73 of the urban areas studied. Almost twice this amount (1,045 million daily vehicle-miles of travel, 75 percent) traveled on 55,743 lane-miles of freeway (68 percent) that had active service patrols in place in 69 of the urban areas.

**Exhibit 14. Freeway Incident Management Inventory – 79 Areas**

Population Group	Average Covered Freeway Travel		Average Covered Freeway Lane-miles	
	Daily VMT (000)	Percentage	Lane-miles	Percentage
<b>Surveillance Cameras</b>				
Very Large (14)	31,279	57	1,520	52
Large (27)	7,216	42	413	37
Medium (25)	2,754	40	181	34
Small (7)	1,611	43	110	39
73 Area Average	9,765	50	517	44
73 Area Total	712,868	50	37,732	44
<b>Service Patrols</b>				
Very Large (14)	44,327	81	2,208	76
Large (29)	11,252	69	668	63
Medium (18)	4,037	55	312	49
Small (8)	3,165	81	212	74
69 Area Average	15,142	75	832	68
69 Area Total	1,044,850	75	55,743	68

Source: HPMS (4), IDTS (2), and TTI Analysis

The effects of incident management programs are shown in Exhibit 15. Seventy-nine of the urban areas had either camera surveillance, freeway service patrols, or both. Overall, the benefits of incidents management were a reduction in the TTI of 0.021 (6.0 percent) and a reduction in freeway hours of delay of 137.1 million hours (7.6 percent). Some of the other findings include:

- The greatest reduction in the TTI occurred in the Very Large areas with a reduction of 0.021 (4.4 percent). The Very Large areas also had the greatest delay reduction of almost 103 million hours (8.0 percent).

**Exhibit 15. Freeway Incident Management Program Effects – 79 Areas**

Population Group	Freeway Travel Time Index			Freeway Hours of Delay (million)		
	Base	With Incident Management	Reduction	Base	With Incident Management	Reduction
Very Large (14)	1.479	1.450	0.021	1,284.4	1,181.7	102.7
Large (29)	1.254	1.240	0.014	424.9	395.5	29.4
Medium (27)	1.128	1.124	0.004	86.9	82.6	4.3
Small (9)	1.058	1.054	0.004	6.5	5.9	0.6
79 Area Average	1.353	1.332	0.021	1,802.8	1,665.7	137.1

Source: TTI Analysis

**Effects of Incident Management in All 90 Areas**

This section shows the effects of incident management as it relates to all 90 urban areas studied. Exhibit 16 shows that over 713 million daily vehicle-miles of travel (48 percent) occurred on 37,732 lane-miles of roadway (41 percent) that were monitored with some form of camera surveillance in all 90 of the urban areas. Almost twice this amount (1,045 million daily vehicle-miles of travel, 71 percent) traveled on 57,745 lane-miles of freeway (63 percent) that had active service patrols in place in the 90 urban areas.

**Exhibit 16. Freeway Incident Management Inventory – 90 Areas**

Population Group	Average Covered Freeway Travel		Average Covered Freeway Lane-miles	
	Daily VMT (000)	Percentage	Lane-miles	Percentage
<b>Surveillance Cameras</b>				
Very Large (14)	31,279	57	1,520	52
Large (29)	6,718	41	384	36
Medium (31)	2,221	35	146	30
Small (16)	705	26	48	20
90 Area Average	7,920	48	419	41
90 Area Total	712,868	48	37,732	41
<b>Service Patrols</b>				
Very Large (14)	44,327	81	2,247	76
Large (29)	11,252	69	672	63
Medium (31)	2,343	37	157	32
Small (16)	1,583	58	120	51
90 Area Average	11,609	71	642	63
90 Area Total	1,044,850	71	57,745	63

Source: HPMS (4), IDTS (2), and TTI Analysis

The effects of incident management programs are shown in Exhibit 17. Seventy-nine of the urban areas had either camera surveillance, freeway service patrols, or both. Overall, the

benefits of incidents management were a reduction in the TTI of 0.021 (6.0 percent) and a reduction in freeway hours of delay of 137.1 million hours (7.6 percent). Some of the other findings include:

- The greatest reduction in the TTI occurred in the Very Large areas with a reduction of 0.029 (6.1 percent). The Very Large areas also had the greatest delay reduction of 102.7 million hours (8.0 percent).

**Exhibit 17. Freeway Incident Management Program Effects – 90 Areas**

Population Group	Freeway Travel Time Index			Freeway Hours of Delay (million)		
	Base	With Incident Management	Reduction	Base	With Incident Management	Reduction
Very Large (14)	1.479	1.450	0.029	1,284.4	1,181.7	102.7
Large (29)	1.254	1.240	0.014	424.9	395.5	29.4
Medium (31)	1.121	1.116	0.005	90.0	85.7	4.3
Small (16)	1.049	1.046	0.003	7.4	6.8	0.6
90 Area Average	1.347	1.326	0.021	1,806.8	1,669.7	137.1

Source: TTI Analysis

## ACCESS MANAGEMENT PROGRAMS

### *What Does Access Management Do?*

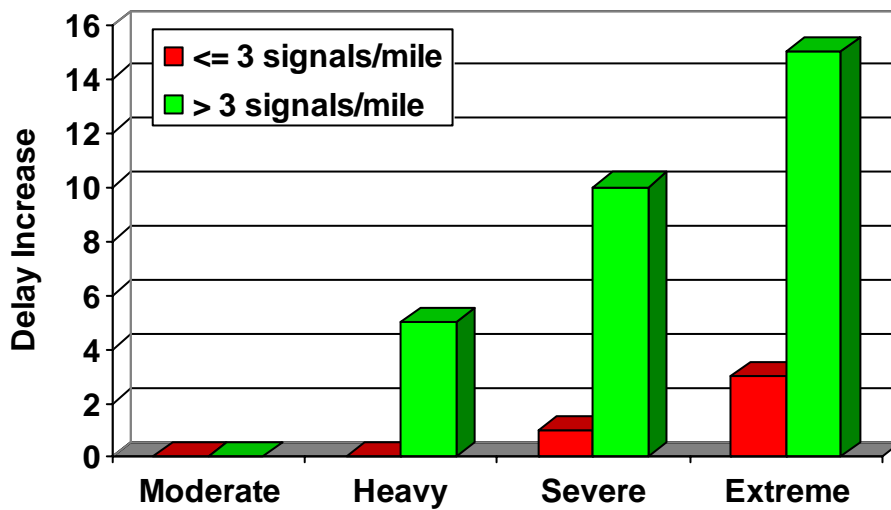
Providing smooth traffic flow and reducing collisions are the goal of a variety of individual treatments that make up a statewide or municipal access management program. Typical treatments include consolidating driveways to minimize the disruptions to traffic flow, median turn lanes or turn restrictions, acceleration and deceleration lanes and other approaches to reduce the potential collision and conflict points. Such programs are a combination of design standards, public sector regulations and private sector development actions. The benefits of access management treatments are well documented in National Cooperative Highway Research Program (NCHRP) Report 420 (17).

### *Estimating the Delay Reduction Effects*

NCHRP Report 395 analyzed the impacts of going from a TWLTL to a raised median for various access point densities and traffic volumes (18). Tables produced in NCHRP Report 395 were used in the Urban Mobility Report methodology to obtain delay factors for both recurring and incident delay.

There is an increase in recurring delay for through and left-turning traffic when going from a TWLTL to a raised median. This increase is primarily due to the storage limitations of select turn bay locations with the raised median treatments. As the turn bays become full, traffic spills out into the through lanes and increases the delay of through vehicles. This situation worsens with increased congestion levels and increased signal density (17). The percent increase factors shown in Exhibit 18 are applied to the recurring delay on the principal arterial streets to account for this increased delay.

**Exhibit 18. Access Management  
Recurring Delay Effects**



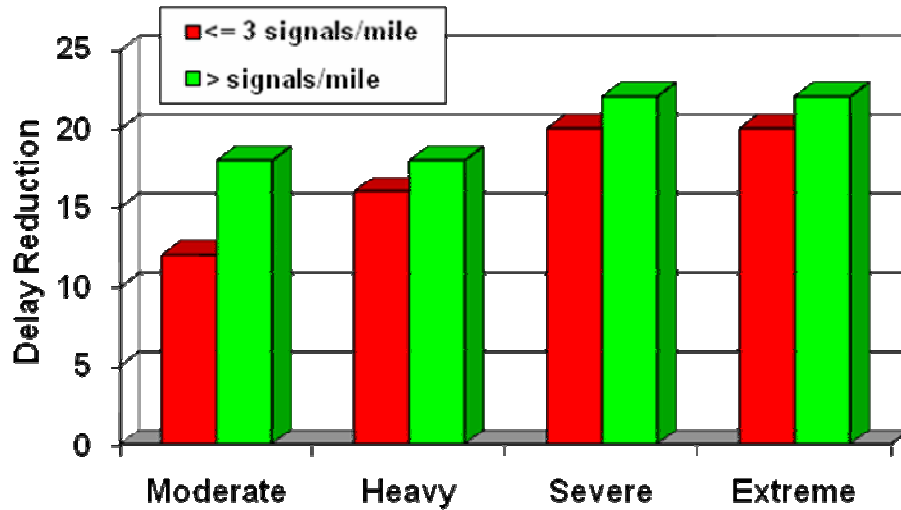
Source: HPMS and TTI Analysis

Raised medians can increase roadway safety by reducing the number of conflict points and managing the location of the conflict points. The reduction in conflict points equates to a reduction in crashes. This benefit of the raised medians was included in the methodology. The delay factors were generated for roadways going from a TWLTL to a raised median. Exhibit 19 shows the percent reduction factors that range from 12 percent at low signal density ( $\leq$  signals/mile) and the lowest congestion level to 22 percent at high signal density ( $>3$  signals/mile) and the highest congestion level (18). These percent reduction values are applied to the incident delay on the principal arterial streets in the methodology.

*Estimated Delay Reduction*

Effects of Access Management in all 90 areas reported some level of access management in 2007, with the coverage representing just over a third of the street miles in the urban areas (7,11). Exhibit 20 displays the vehicle-miles of travel and lane-miles of principal arterial streets that included access management treatments. In the 90 areas studied, over 495 million daily vehicle-miles of travel (35 percent) occurred on about 80,400 lane-miles of principal arterial streets (30 percent) that contained access management treatments.

### Exhibit 19. Access Management Incident Delay Effects



Source: HPMS and TTI Analysis

### Exhibit 20. Principal Arterial Access Management Inventory

Population Group	Average Covered P.A.S. Travel		Average Covered P.A.S. Lane-miles	
	Daily VMT (000)	Percentage	Lane-miles	Percentage
Very Large (14)	20,020	38	3,207	34
Large (29)	5,068	34	823	30
Medium (31)	1,829	27	315	23
Small (16)	709	19	115	15
90 Area Average	5,503	35	893	30
90 Area Total	495,293	35	80,393	30

Source: HPMS (4), IDTS (2), and TTI Analysis

Overall, access management reduced the arterial TTI by 0.008 (3.0 percent) and reduced the arterial hours of delay by 60.6 million hours (2.9 percent). Some of the results of access management include (Exhibit 21):

- The Very Large urban areas had the greatest point reduction in the TTI (0.010) as well as the largest reduction in delay (38.2 million hours).
- The largest percentage decreases occurred in the Very large with a 3.1 decrease in the TTI and a 3.0 reduction in arterial delay.

### Exhibit 21. Principal Arterial Access Management Effects

Population Group	Principal Arterial Travel Time Index			Principal Arterial Hours of Delay (million)		
	Base	with Signal Coordination	Reduction	Base	With Signal Coordination	Reduction
Very Large (14)	1.324	1.314	0.010	1,268.0	1,229.8	38.2
Large (29)	1.242	1.235	0.007	559.0	542.4	16.6
Medium (31)	1.168	1.164	0.004	200.0	195.0	5.0
Small (16)	1.140	1.138	0.002	49.4	48.6	0.8
90 Area Average	1.269	1.261	0.008	2,076.3	2,015.7	60.6

Source: TTI Analysis

## HOV LANES

### *What Are HOV Lanes?*

HOV lanes are exclusive roadways or lanes designated for high occupancy vehicles, such as buses, vanpools, and carpools. The facilities may operate as HOV lanes full time or only during the peak periods. HOV lanes typically require minimum vehicle occupancy of two or more persons. However, in some locations, occupancy requirements have been raised to preserve the high speeds on the facility. Support facilities such as park and ride lots and transit centers with direct access to the HOV lane are important system elements to increase facility use. HOV lanes may also be used to provide bypass lanes on entrance ramps with ramp meter signals. Several common types of HOV lanes are barrier separated, concurrent flow, and contra flow lanes.

- Barrier-separated lanes are typically constructed in the center of the freeway and physically separated from the general-purpose lanes with concrete barriers. Single lane facilities operate as reversible lanes, flowing in one direction during the morning period and the other direction in the evening period. Multiple lane facilities may either be operated as two-way facilities or reversible facilities.
- Concurrent flow HOV lanes (commonly the inside lane) operate in the same direction of flow as the general-purpose lanes and are usually separated from the general-purpose lanes by a small buffer and wide paint stripe.
- Contra flow lanes make use of the inside off-peak direction general-purpose lane during the peak period. Movable concrete barriers are used on several facilities around the U.S..

### *Estimating the Delay Reduction Effect*

Providing reliable and high-speed travel improves corridor mobility levels where HOV service is available. We will use evaluations or operating statistics of individual lanes that have reliable speed and person travel volume information. The HOV travel statistics will be added to the current freeway and principal arterial street system information for each area to produce an areawide effect on the Travel Time Index.



*Urban Mobility Report Procedures*

An HOV Travel Time Index is calculated for each city with HOV data. This HOV TTI is combined with the traditional UMR freeway TTI by weighting the freeway passenger-miles of travel with the HOV passenger-miles of travel. The difference between the combination and the traditional UMR freeway TTI displays the effects. Similarly, the amount of delay that is saved by having persons in the HOV lane and not the freeway mainlanes is calculated as well.

*Estimated Delay Reduction*

**Effects of HOV Lanes in 8 Areas Where Implemented**

High-occupancy vehicle data has been included from eight urban areas in the U.S. (Exhibit 22). This does not include information from all of the existing HOV lanes in the country, but only those where readily available statistics were available. Also, year 2000 data has been used in 2003 due to difficulty in obtaining the data. Ten of these areas are Very Large and six are Large. No Medium or Small areas have HOV information included. The average passenger-miles of travel (PMT) in the ten Very Large areas is about 1,857,000 miles a day while the average PMT for the Large areas is about 353,000 miles a day. There were approximately 20.7 million passenger-miles of travel on the HOV lanes in these areas.

**Exhibit 22. Freeway High-Occupancy Vehicle Lane Inventory – 16 Areas**

<b>Population Group</b>	<b>HOV Lane Daily Passenger-miles of Travel (000)</b>
Very Large (10)	1,857
Large (6)	353
Medium (0)	–
Small (0)	–
16 Area Average	1,293
16 Area Total	20,688

Source: Local agencies and TTI Review

Exhibit 23 displays the effects generated by HOV lanes. The HOV lane ridership included in the analysis lowered the freeway TTI by 0.018 (3.7 percent) and the freeway hours of delay by 37.0 million hours (3.1 percent) in these sixteen urban areas. Some additional statistics include:

- The HOV lanes lowered the freeway Travel Time Index values by 0.021 in the Very Large and 0.010 in the Large urban areas.
- There were approximately 33.8 million hours of delay saved per year by passengers using the HOV lanes in the Very Large urban areas and 3.2 million hours saved in the Large areas.

**Exhibit 23. Freeway HOV Lane Effects – 16 Areas**

Population Group	Freeway Travel Time Index			Freeway Hours of Delay (million)		
	Base	With HOV	Reduction	Base	Reduction due to HOV	Percent of Base Delay
Very Large (10)	1.513	1.492	0.021	1,057.3	33.8	3.2
Large (6)	1.355	1.345	0.010	746.8	3.2	0.01
Medium (0)	—	—	—	—	—	—
Small (0)	—	—	—	—	—	—
16 Area Average	1.487	1.469	0.018	1,199.8	37.0	3.1

Source: TTI Analysis

**Effects of HOV Lanes in All 90 Areas**

This portion of the analysis will show the effects that HOV lanes in 16 areas have on the 90 urban areas studied. High-occupancy vehicle data has been included from eight urban areas in the U.S. (Exhibit 24). This does not include information from all of the existing HOV lanes in the country, but only those where readily available statistics were available. Ten of these areas are Very Large and six are Large. No Medium or Small areas have HOV information included. This data is from the year 2000 and has not been updated due to the difficulty of obtaining the information. The average passenger-miles of travel (PMT) in the ten Very Large areas is just over a 1.3 million miles a day while the average PMT for the Large areas is about 73,000 miles a day. There were approximately 20.7 million daily passenger-miles of travel on the HOV lanes in these areas.

**Exhibit 24. Freeway High-Occupancy Vehicle Lane Inventory – 90 Areas**

Population Group	HOV Lane Daily Passenger-miles of Travel (000)
Very Large (14)	1,326
Large (29)	73
Medium (31)	—
Small (16)	—
90 Area Average	230
90 Area Total	20,688

Source: Local agencies and TTI Review

Exhibit 25 displays the effects generated by HOV lanes. The HOV lane ridership included in the analysis lowered the freeway TTI by 0.009 (2.6 percent) and the freeway hours of delay by 37.0 million hours (2.1 percent) in these sixteen urban areas. Some additional statistics include:

- The HOV lanes lowered the freeway Travel Time Index values by 0.016 in the Very Large and 0.002 in the Large urban areas.
- There were approximately 33.8 million hours of delay saved per year by passengers using the HOV lanes in the Very Large urban areas and 3.2 million hours saved in the Large areas.

**Exhibit 25. Freeway HOV Lane Effects – 90 Areas**

Population Group	Freeway Travel Time Index			Freeway Hours of Delay (million)		
	Base	With HOV	Reduction	Base	Reduction due to HOV	Percent of Base Delay
Very Large (14)	1.479	1.463	0.016	1,275.9	33.8	2.7
Large (29)	1.254	1.252	0.002	424.6	3.2	0.8
Medium (31)	1.121	—	—	90.0	—	—
Small (16)	1.049	—	—	7.4	—	—
90 Area Average	1.347	1.338	0.009	1,797.9	37.0	2.1

Source: TTI Analysis

## **PUBLIC TRANSPORTATION**

### *What is Public Transportation?*

The buses and trains that comprise the majority of public transportation carry a significant amount of trips in many large areas and provide some important benefits in smaller areas. Peak period public transportation service during congested hours can improve the transportation capacity, provide options for travel mode and allows those without a vehicle to gain access to jobs, school, medical facilities or other destinations. In the case of public transportation lines that do not intersect roads, the service can be particularly reliable as they are not affected by the collisions and vehicle breakdowns that plague the roadway system, and are not as affected by weather, road work and other unreliability producing events. This section provides an estimate of the benefits of general public transportation service and high-occupancy vehicle lane operations.

### *Estimating the Delay Reduction Effect*

The process of including transit service in a mobility measure must recognize that there are differences between estimates of mobility on roads and the concept of mobility in transit service. There are some similarities that can provide a basis for comparison, but an evolutionary approach to including public transportation service seems to make sense. This has proven useful on the roadway measures research efforts where the data, procedures and measures have changed as different needs were identified or new data became available. Using the best available data and models to produce estimates of the performance measures and improving the estimates and measures over the next few years as the needs are better understood and the knowledge is enhanced appears to be a reasonable course.

The available data sources do not readily lend themselves to estimates of peak period travel speed and person travel on transit. There may be ways to estimate these factors from a combination of nationally consistent databases and local studies or databases, but it is important to have a theoretical basis for the assumptions made in the analyses. The best time comparison would seem to use the peak period, and person travel appear to be the best way to capture the mobility provided by public transportation.

A significant potential source of confusion is in translating the roadway mobility concept of congestion into urban transit operations. There are several differences between what constitutes congestion and free-flow travel on roads and the same concepts on transit, but there also appears to be a common ground in the concept of what travel conditions are desirable. It is reasonable to assume that transit riders plan their trip based on the schedules and operating headways of the transit service. The expected performance, then, is for the train or bus to arrive on schedule. This would be equivalent to the roadway concept of free-flow travel. In this relationship, “on-time transit” would be equivalent to “uncongested roadway.”

At first glance, it might appear overly generous to evaluate transit operations without an estimate of the travel speed. But, the service characteristics and expectation are very different. Local bus routes typically travel slower than the private vehicles on the same street because they stop to allow riders to enter and exit the bus. Rail routes may be faster or slower depending on the amount of interference with general vehicle traffic and station spacing. Transit routes can gain speed by decreasing stops, but at the risk of losing ridership. This relationship between speed and convenience is constantly adjusted by transit agencies seeking to increase transit service and ridership.

This approach to defining a “free-flow” speed for transit routes would result in a slower speed relative to the adjacent vehicle traffic on the same roadway. This might appear inconsistent, but two factors appear relevant.

- There is already a different speed threshold for streets and freeways. Vehicle travel on streets is graded against a free-flow speed of 35 mph compared to the freeway speed of 60 mph.
- Bus riders use the schedule speed to make their travel mode decisions. In doing this, the riders understand that travel might be slower or faster than adjacent street or freeway traffic. The “penalty” or “reward” for public transportation in this mobility estimate comes from gain or loss in ridership. If the route travel times become unreasonably long, ridership will decline, and the amount of “uncongested” passenger-miles contributed by public transportation will also decline. The beneficial effects of faster route times, better access or improved service from interconnected networks or high-speed bus or rail links would result in higher ridership values, which would increase the amount of “uncongested” travel in the mobility measure calculations.

Extending the concept of different “desirable” speeds to transit service analysis will provide a good measure of mobility, as well as simplifying the data requirements to the elements that might be available or estimated.

### *Urban Mobility Report Procedures*

The passenger miles of travel from public transportation are included into the daily passenger-miles of travel on the roadways in order to calculate the TTI and delay savings. All transit PMT is included as uncongested travel to calculate the TTI, and the transit PMT is added to the existing mix on the roadways to calculate delay savings.

## Estimated Delay Reduction

### Effects in All 90 Areas

In the 90 urban areas studied, Exhibit 26 shows that there were approximately 50 billion passenger-miles of travel on public transportation systems in 2007. The annual ridership ranged from about 16 million in the Small urban areas to about 3.0 billion in the Very Large areas.

**Exhibit 26. Public Transportation Inventory – 90 Areas**

Population Group	Public Transportation Annual Passenger-miles of Travel (million)
Very Large (14)	2,972
Large (29)	213
Medium (31)	55
Small (16)	16
90 Area Average	553
90 Area Total	49,790

Source: APTA Operating Statistics (6) and TTI Review

Exhibit 27 shows the effects of public transportation in the 90 areas studied. Overall, public transportation lowered the TTI by .018 (5.8 percent) and accounted for a reduction in roadway delay of about 630 million hours or 16.2 percent of total delay. Some additional effects include:

- The largest reduction in the TTI occurred in the Very Large areas with a reduction of 0.036 (8.9 percent). The Very Large areas experienced a reduction in delay of over 557 million hours per year (almost 22 percent of total delay).
- The Large urban areas experienced the second largest reduction in the TTI and delay with a reduction of 0.005 points (2.0 percent) to the TTI and over almost 59 million hours of delay per year (6 percent of total delay).

**Exhibit 27. Effects of Public Transportation – 90 Areas**

Population Group	System Travel Time Index			System Hours of Delay (million)		
	Base	with Public Transportation	Reduction	Base	Reduction due to Transit	Percent of Base Delay
Very Large (14)	1.403	1.367	0.036	2,552.4	557.0	21.8
Large (29)	1.248	1.243	0.005	983.9	58.8	6.0
Medium (31)	1.144	1.143	0.001	290.0	12.8	4.4
Small (16)	1.102	1.101	0.001	56.9	1.5	2.6
90 Area Average	1.309	1.291	0.018	3,883.2	630.1	16.2

Source: TTI Analysis

## *Future Improvements to Public Transportation Analysis*

A longer-term approach will be to develop links with the public transportation operations databases that some agencies have. These include travel time, speed and passenger volume data automatically collected by transit vehicle monitoring systems. Linking this data with the roadway performance data in public transportation corridors would be the logical extension of the archived roadway data inclusion efforts being funded by the Federal Highway Administration. An alternative to the real-time data would be to estimate public transportation vehicle travel time and speed information from route schedules, and combine them with the passenger loading information collected by the public transportation systems. While these data are not reported in nationally consistent formats, most public transportation systems have this type of information.

## *Full Implementation of Operational Treatments*

### **What if the 90 Urban Areas had Full Implementation?**

What sort of impact would the treatments make if all 90 urban areas had them implemented on 100 percent of their roadway system? An analysis was performed to answer this question. Full implementation of all four treatments would lower the Travel Time Index by 0.035 points resulting in an annual delay savings of almost 490 million hours. This level of implementation would save each person in the 90 areas over four hours per year, an amount equal to four or five years of growth.

Exhibit 28 shows that with 100 percent implementation of ramp metering, the TTI could be lowered by 0.016 points to 1.331 in the 90 urban areas. This equates to almost 100 million hours of delay that would be saved. Over three-quarters of the delay savings would occur in the Very Large areas. Ramp meter delay reduction benefits would be a combination of recurring and incident delay.

The incident management program would also show significant benefits from full implementation with a reduction of 0.028 points to 1.319 in the 90 urban areas. This reduction equals over 186 million hours of delay that would be eliminated. This value is a product of reducing the incident delay only and does not include the improved reliability that would result from reducing the long duration collision scenes.

If 100 percent of the signal systems were progressive, the amount of delay reduction in the 90 urban areas would approximately double. The TTI would be reduced by 0.005 points. The annual delay savings associated with full implementation would equal about 37 million hours.

If 100 percent of the arterial streets had access management, the TTI would drop by 0.015 in the 90 areas studied. This would equate to an annual delay savings of 131 million hours.

The largest delay reduction improvements would occur in the Very Large and Large areas where the most travel and delay occurs, but the efficiency improvements in areas of all sizes are important aspects of achieving the most productivity from the available capacity.

**Exhibit 28. Full Implementation of Operational Treatments**

	TTI		Total Annual Delay (million hours)	
	Base	100% full implementation	Base	100% full implementation
<b>Freeway Statistics</b>				
Ramp Metering				
Very Large (14)	1.479	1.456	1,284	1,209
Large (29)	1.254	1.244	425	404
Medium (31)	1.121	1.118	90	87
Small (16)	1.049	1.048	7	7
90 Areas	1.347	1.331	1,807	1,708
Incident Management				
Very Large (14)	1.479	1.442	1,284	1,153
Large (29)	1.254	1.234	425	382
Medium (31)	1.121	1.111	90	80
Small (16)	1.049	1.044	7	6
90 Areas	1.347	1.319	1,807	1,621
<b>Principal Arterial Statistics</b>				
Signal Coordination				
Very Large (14)	1.324	1.318	1,268	1,244
Large (29)	1.242	1.238	559	549
Medium (31)	1.168	1.165	200	197
Small (16)	1.140	1.139	49	48
90 Areas	1.269	1.264	2,076	2,039
Access Management				
Very Large (14)	1.324	1.305	1,268	1,185
Large (29)	1.242	1.229	559	525
Medium (31)	1.168	1.159	200	188
Small (16)	1.140	1.133	49	47
90 Areas	1.269	1.254	2,076	1,945
<b>Four Operational Treatment Statistics</b>				
Very Large (14)	1.403	1.354	2,552	2,205
Large (29)	1.248	1.223	984	873
Medium (31)	1.145	1.328	290	262
Small (16)	1.102	1.095	57	52
90 Areas	1.309	1.274	3,883	3,393

Source: TTI Analysis

## CONCLUSIONS

The purpose of this analysis is not to draw comparisons between strategies to determine which one is providing the most benefit. The purpose is simply to estimate the benefits at an urban area level using a consistent methodology. Each of the urban areas in the study has different characteristics that might make one strategy more viable than another and each area implements the strategies in different ways. Thus, analyzing the effects across urban areas may not provide a valid comparison. Technologies, operating practices, programs and strategies provide methods to get the most efficiency out of the road and transit capacity that is built, sometimes for modest costs and low environmental effects. In some cases, the operational improvements are some of the few strategies that can be approved, funded and implemented, and all of the strategies analyzed in the report have been shown to be very cost effective at the individual project level.

For years, the statistics in the Annual Urban Mobility Report have shown that traffic congestion continues to increase. The report has also stated that urban areas need to use a diverse set of solutions to deal with the mobility problem. This analysis shows that some of the possible solutions to the problem are making a difference in the struggle with congestion. Obviously, more strategies are needed and greater implementation of these solutions is needed in many areas to keep up with the growing demand on the transportation system.



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