MAG NON-RECURRING CONGESTION STUDY

MAG Contract No. 418 Project No. PL10-1
Technical Memorandum No. 1 – DRAFT Literature Review and Taxonomy

INTRODUCTION

The Lee Engineering/TTI team is conducting a study on non-recurring congestion for the Maricopa Association of Governments. This technical memorandum is the first in a series to document the effort on the study. Technical memorandum #1 summarized the work completed on Task 1 – Literature Review. The literature review task consisted of three components: 1) reviewing existing literature on sources of congestion, 2) reviewing existing literature on countermeasures to non-recurring congestion, and 3) developing taxonomy on non-recurring congestion terms.

SOURCES OF CONGESTION

TTI's 2009 Mobility Report (Shrank, Lomax 2009) ranks the Phoenix urban area in the top 15 within the U.S. in terms of total congestion, delay per person, and the cost of congestion. These mobility measures consist of both recurring and non-recurring sources of congestion. Research from the US Department of Transportation summarizes the national sources of congestion as shown in Figure 1.

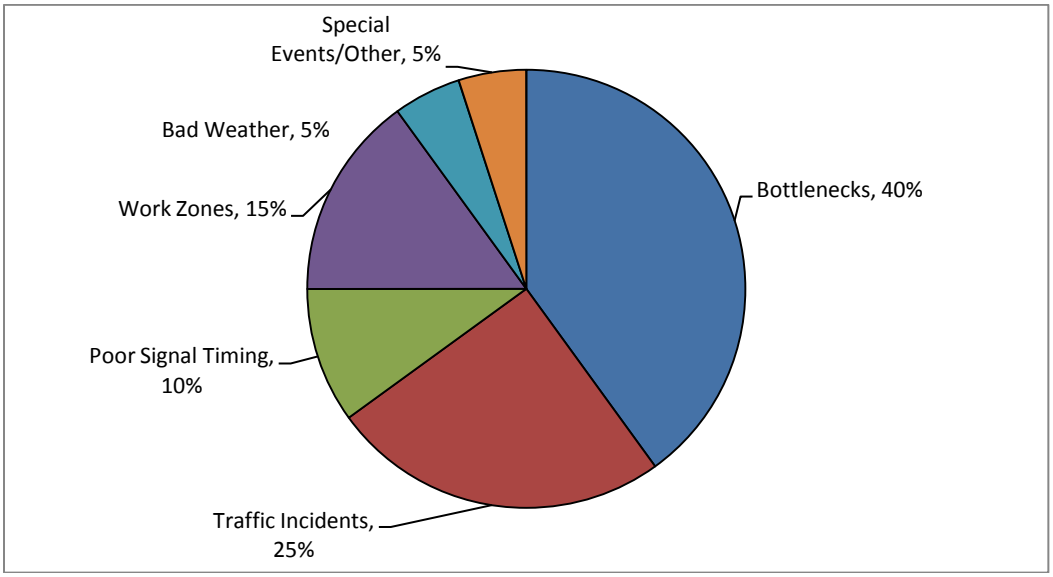

Figure 1. Sources of Total Congestion

An observation regarding non-recurring congestion and its place in the bigger picture of overall roadway congestion is found in Alan Pisarski's book *Commuting in America III.* Pisarski states "Certainly one of the central findings of this work is that many of the congestion problems we face are a product of vehicle breakdowns, construction and repair activities on the roadway, weather and poor signal timing – all of which have ameliorative solutions that do not involve building new facilities. It is this finding that has given rise to efforts at better management of facilities, improved information and more rapid response to unexpected events. (Pisarski, 2007, p. 129)." Pisarski also presents the relative sources of congestion with results from two major studies. The charts from that discussion are recreated here as Figure 2A and Figure 2B.

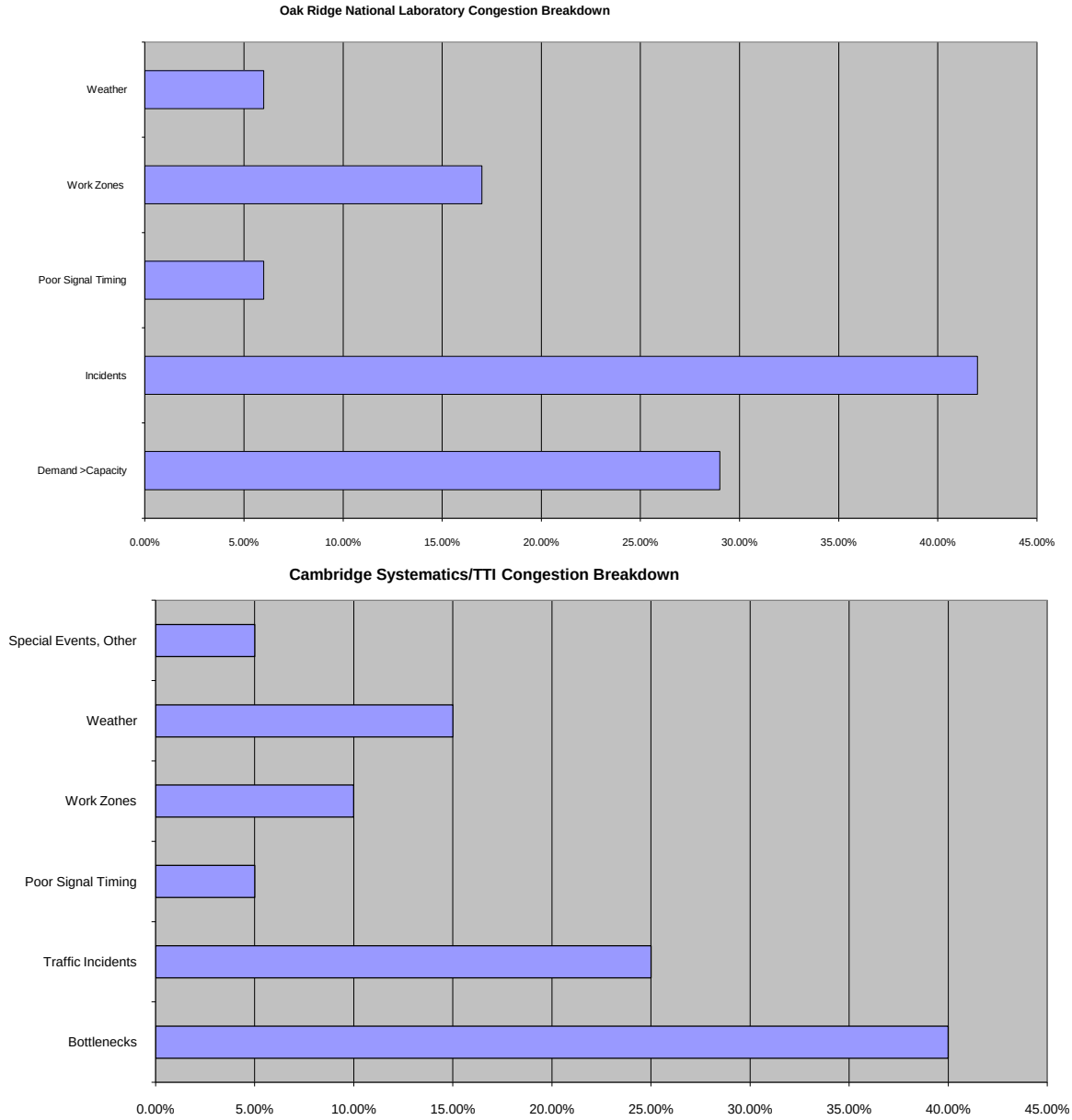

Figure 2A, 2B – Sources of Congestion from Varying Studies

Pikarski further observes "The fact that these approaches differ is not a criticism of either but rather an indication of early stages of investigation we are in today. These numbers must be considered as estimates, and are very preliminary in character in both their value and structure. Note that the ORNL approach gives a smaller share to demand-exceeding-capacity problems (labeled bottlenecks in the Cambridge Systematics, Inc/TTI work) and also to weather problems."

A report from Washington State describes the factors that cause congestion to form by discussing the results of a series of analyses that examine congestion on freeways in the greater Seattle region (Washington State Department of Transportation). This research effort uses measured roadway performance data for an entire year on roughly 120 miles of urban freeway, and includes all crashes and non-crash related incidents in which WSDOT personnel responded, and weather data for the region. The author states that the seven sources of congestion are traffic incidents, weather, work zones, fluctuations in demand, special events, traffic control devices, and bottlenecks/inadequate base capacity. The study found that rain influenced almost as much of the observed congestion as vehicle crashes.

A study in California described a methodology that was developed to identify and measure recurrent and non-recurrent congestion on freeways using loop detectors or other surveillance systems (Skabardonis, Varaiya, & Petty, Measuring Recurrent and Nonrecurrent Traffic Congestion, Paper No. 03-4261, 2003). Two factors were considered when measuring non-recurrent delay in this research: accidents (any event that involved vehicle collisions) and non-accident incidents (breakdowns, debris, other traffic hazards, etc.). The methodology was applied to three real-life freeway corridors in California: I-210, I-880, and I-10. The study concluded that non-recurrent delay was between 13% and 30% of the total delay along the three study corridors, and this portion of delay depends heavily on the extent of recurrent delay.

Sources of Non-Recurring Congestion

A study by Oak Ridge National Laboratory further categorized the causes of non-recurring congestion. Non-recurring congestion is also sometimes referred to as temporary loss of capacity (TLC). According to a study by the Oak Ridge National Laboratory, the primary causes and contribution of non-recurring delay include crashes, work zones, vehicle breakdowns, adverse weather and signal timing (Chin, Franzese, Greene, & Hwang, 2002). Figure 3 presents the relative frequency of these causes of non-recurring congestion according to ORNL.

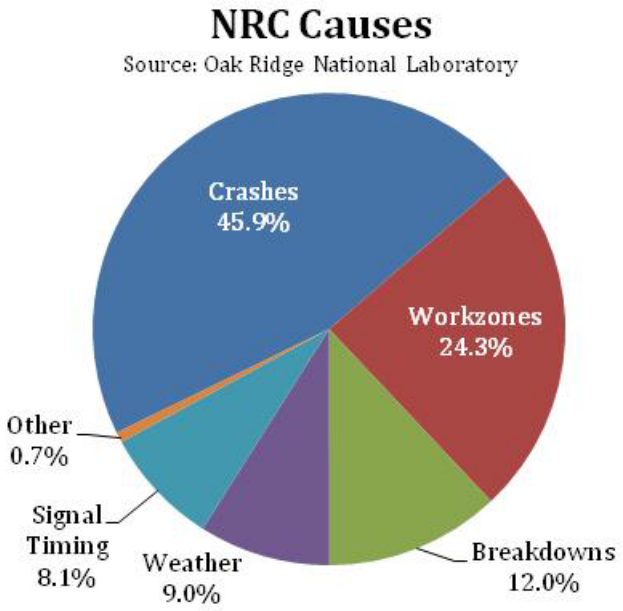

Figure 3 – Sources of Non-Recurring Congestion

A 2003 study (Hallenbeck, Ishimaru, & Nee, 2003) in Washington State focused on non-recurring congestion on urban freeways resulting from lane-blockages found:

- The percentage of delay resulting from non-recurring congestion was highly variable
- Lane blockage incidents were responsible for 2 to 20% of total daily delay
- Non-recurring delay is responsible for 30-50% of all peak period, peak direction delay but is responsible for 30-70% of total daily delay
- Lane blockage incidents generally account for 10-35% of total non-recurring delay
- Only 1-10% of peak period delay was caused by lane blockage incidents due to high levels of recurring congestion and the relatively infrequency of lane blockages during the peak periods.
- Expressing non-recurring delay as a percentage of total congestion does not adequately describe the magnitude of the problem because the number of vehicle hours of non-recurring delay can increase significantly

Source - Incidents

A lane blocking incident of a short duration during a peak or near-peak period can result in substantial delays well after the blockage is removed. In Phase 2 of this study, the test was extended to include an examination of the effects of incidents involving the shoulders of the freeway; spillback from incident-caused congestion on one freeway that affects a second freeway that feeds traffic onto the initially congested facility; special events; and weather (Kopf, Nee, Ishimaru, & Hallenbeck, 2005).

The Washington State project showed that this process can be automated, making the data preparation effort now the primary determinant of the cost of additional work of this kind. Unfortunately, even with the addition of shoulder incidents, special events, and weather to lane blocking events, the automated process was unable to assign a significant proportion of the non-recurring delay occurring on Seattle freeways. The detailed analysis of freeway performance showed that much of the delay caused by specific incidents occurs in places or at times removed from the incident itself. The result is that much of the observed non-recurring delay cannot be assigned to specific causes by the current analytical process. The Phase 2 analysis also confirmed that the congestion effects of specific incidents and other traffic disruptions are highly dependent on the background traffic conditions at the time of the disruption.

A study by the University of California Irvine further looked at the contribution of incident characteristics on the congestion caused by the incidents. The report provided a review of a research project for measuring non-recurring congestion impacts of accidents (Recker, Golob, & Yazdan, 2007). The objective of this project was to develop and apply an analytic procedure that estimates the amount of traffic congestion (vehicle hours of delay) that is caused by different types of accidents that occur on urban freeways in California. Computations of non-recurring delay were successfully performed for 870 accidents that occurred on weekdays throughout the period of March through December 2001 on the six major Orange County non-toll freeways. The results of the study indicate that the following accident characteristics are crucial in identifying those accidents that are likely to cause the most delay: (a) how many vehicles are involved in any accident occurring during the weekday AM peak, and whether the accident is in the left lane or not, (b) how many vehicles are involved in an accident occurring in the midday period, and whether there is a truck involved in the accident, (c) which lane a PM peak period accident is located in, and whether or not it is a single-vehicle accident, (d) whether or not a truck is involved in any accident, and finally, (e) whether or not the accident occurs on Friday.

Another study in California analyzed the data on I-880. The study presented the findings from the analysis of incident data collected as part of the I-880 field experiment, originally conducted to evaluate the effectiveness of the freeway service patrols implemented at a particular freeway section (Skabardonis, Petty, Bertini, Varaiya, Noeimi, & Rydzewski, 1997). The I-880 field experiment produced one of the largest databases on incidents and freeway traffic-flow characteristics at the time, which included data on incidents and speed-flow-occupancy rates, and probe-vehicle runs (at seven minute headways) along the study corridor.

The researchers define incidents as accidents, vehicle breakdowns, spilled loads, or any other random event that reduces the capacity of the road and causes congestion if the traffic demand exceeds the reduced capacity at the incident location. The impact of incidents on traffic flow depends on the incident frequency, location, type, severity, and duration; the traffic demand and capacity at the facility; and the availability of incident management programs. The results of the field data analysis revealed that during the study, there was an average of 47 incidents per day during the peak period. Most of these incidents were vehicle breakdowns on the shoulder, but 10% were accidents, and 4% blocked travel lanes. Time of day, day of the week, presence of shoulders, traffic volumes, and weather conditions accounted for the variability in the incident occurrence. Incident response, clearance times, and durations was reduced from 29 minutes to 18 minutes, and the response time to assisted breakdowns was reduced by 57% after the implementation of freeway service patrols.

Source – Weather

In a Washington State study, researchers evaluated the qualitative relationship between weather patterns and surface traffic conditions in Seattle using data from two data mines at the University of Washington (Dailey, 2006). Seven freeway loops in north Seattle that were paired with inductance loops and in a known convergence zone (known to expect more rainfall) were examined in this study. The research concluded that while rainfall does affect traffic conditions, other congestion causes may outweigh the effect of weather.

Impacts on Freight Industry

Congestion also has an impact on the trucking and freight industry. The trucking industry moves nearly 60 percent of the tons of freight in the U.S. Freight moved by trucks is dependent on the transportation roadway infrastructure and the level-of-service maintained on those roadways. Congestion on these roadways is a cost to the trucking industry, but non-recurring congestion has a greater impact due to its unpredictable nature.

A New Jersey study on congestion impacts to the trucking industry notes that “Recurring delay (delay due to congestion) is detrimental to the movement of freight on the highway. But, when accounted for, recurring delay can be accounted for in trucking companies’ cost calculations and scheduling. Non-recurring delay . . . cannot be anticipated due to the unpredictable nature of its occurrence. As such, trucking companies cannot adjust cost calculations and schedules giving less reliability in the delivery time of goods (especially in congested urban areas during peak hours). (Rensselaer Polytechnic Institute, 2007)”

COUNTERMEASURES FOR NON-RECURRING CONGESTION

This section of the technical memorandum discusses literature findings on countermeasures for non-recurring congestion. The countermeasures listed here are grouped by the source of non-recurring congestion that can be reduced by a given countermeasure.

Countermeasures for Congestion Caused by Incidents

Because incident congestion is a major factor in non-recurring congestion, there are several studies in the literature reviewed that focus on the countermeasures to reduce congestion caused by incidents.

Improved Incident Management Programs/Procedures

Cunard conducted a review of various incident management programs that have been implemented throughout the United States (Cunard, 2000). Cunard used the definition of an incident (mechanical, accident, abandoned vehicles, roadway debris, etc.) as a random event that is unpredictable in relation to its time and location and that non-recurring congestion is typically caused by incidents. He defined incident management as a planned and coordinated, possibly a multi-agency/multi-jurisdictional, process to detect and remove highway traffic disruptions and restore capacity as safely and quickly as possible. The effectiveness of an incident management program depends on how well the following are administered: incident detection, incident verification, incident response, incident site management, traffic management/motorist information, and incident clearance time/recovery. The paper also describes the costs of incident management programs, and provides several examples of programs to suit any budget. Low-cost incident management programs include incident management trailers, route diversion plans (shown through detour signs, DMS, etc.), push bumpers (installed on law enforcement vehicles to remove disabled vehicles), designated accident investigation sites, “Move It” Programs (programs that stress the need for motorists to move vehicles from the roadway after a crash immediately), freeway service patrols, and technological improvement in accident data collection. Medium-cost management programs include major incident response teams, creating an incident reporting telephone number, and telephone call boxes strategically placed along the roadside. High-cost programs include traffic operations centers, incident detection/verification techniques (electronic surveillance, CCTV, AVI, fixed observers, aerial observance), and advance motorist information techniques (DMS, highway radio, traffic reports on television, Internet, etc.).

A paper on incident management in Alabama reports on an approach used to evaluate the mobility-related benefits of freeway service patrols achieved by quicker incident response and clearance as applied to the Alabama Service and Assistance Patrol (ASAP) operating in the Birmingham area (Heath & Turochy, 2009). The evaluation tool uses ASAP data as well as simulation modeling, and also produces a detailed benefit-cost analysis of the ASAP program. The results of the study show that the ASAP program reduced both delay and incident duration, and indicate that the program is cost-effective with regards to incident management.

Another paper on incident management in Florida describes the effort to apply data mining techniques to query service patrol databases for incident analyses (Zhan, Gan, & Hadi, 2006). The Florida DOT applied geocoding techniques to data in the service patrol databases for Broward and Palm Beach Counties to determine the exact location for each “incident” listed to conduct specific incident analyses

on service areas with the highest incident frequency. Incident analysis based on spatial information can be used to identify locations with high incident rates, which could lead to rescheduling service patrol vehicles, changing the services areas, or other methods to improve the service. The results of the study show that geocoding was used to assess the service quality at different service areas and to identify target areas for service improvement.

The Road Ranger program in Florida is a freeway service patrol (FSP) that was designed to assist disabled vehicles along congested freeway segments and also to relieve peak period non-recurring congestion through quick detection, verification, and removal of freeway incidents in the State of Florida (Zhou, Hagen, Singh, & Clark, 2006). It consists of approximately 88 vehicles in fleet and provides its free service to about 918 centerline miles. The program is funded by the Florida Department of Transportation and its partners, and is bid out to private contractors. A study was conducted to examine and evaluate the benefits of the Road Ranger service patrol against their operating costs in five Districts and the Florida Turnpike Enterprise in Florida (Zhou, Hagen, Singh, & Clark, 2006). The Road Ranger program provides direct benefits to the general public in terms of reduced delay, fuel consumption, air pollution and improved safety and security. The benefit would be expected to be more significant during peak periods when demand reaches or exceeds capacity than in off-peak and mid-day periods where capacity may not be as significant an issue. The costs considered in this analysis include costs of administration, operation, maintenance, employee salaries, and overhead costs. Incident data were obtained from the daily logs maintained by the Road Ranger service providers containing important information about the time, duration, location, and type of service provided. Other data collected for this study include average daily traffic volume, geometric characteristics of freeways, unit cost of Road Ranger service, etc. The Freeway Service Patrol Evaluation (FSPE) model developed by the University of California-Berkley was calibrated and used to estimate the benefit-cost ratio for the Road Ranger program. The estimated benefit/cost ratios based on delay and fuel savings indicate that the Road Ranger program produces significant benefits in all five Districts and the Turnpike. The range of benefit to cost ratios of Road Ranger programs in different districts is from 1.51:1 to 21.35:1.

Another study examined the communications aspect of incident management on arterial streets (Raub, 1999). According to the research, the successful and rapid clearance of an incident is dependent on the coordination of operations, expedited removal of elements interfering with traffic, and the consideration of traffic movement and how an incident will affect that movement. The author states that on-scene coordination may be the most important element related to reducing the time that an incident affects traffic. There should be inter-organization communication and an overall command in order to relay the correct information to all parties involved in the management of an incident, such as specific instructions for response, the need for traffic assistance or lane/road closure, etc. The author suggests providing education and training to the public on how to report incidents which will expedite the incident detection, clearance, and recovery time. The author also stresses the importance of communicating with en-route motorists to reduce delay and manage alternate routes should an incident occur.

Improved Traffic Management at Incidents

A study for the Michigan Department of Transportation investigated dynamic lane assignment (Michigan Department of Transportation and Michigan State University, 2003). Upon seeing signs

informing motorists of a merge ahead, drivers will typically take one of two actions: they will merge early, moving from the discontinuous lane as soon as possible, typically creating a long, single-lane queue that moves at slow speeds, or they will merge late, waiting until the last opportunity to switch lanes, staying in the discontinuous lane and often forcing a merge at the point of closure. Dynamic lane merge (DLM) is an ITS technology that can be used in work zones to alleviate the congestion and crashes this mix of reactions can cause. The technology uses electronics and communications equipment to monitor traffic flow and, as queuing increases at approaches to lane closures, regulates the merge, requiring either early merge or late merge depending on traffic conditions. A 2003 Michigan Department of Transportation test of early merge found:

1. Average travel speed increased from 40 to 46 mph during the morning peak period.
2. Crashes were reduced from an average of 1.2 per month during the 4 months prior to activation to no crashes after activation (Michigan Department of Transportation and Michigan State University, 2003).

A study in California looked at both traffic management and incident management impacts on incident congestion (Kwon, Mauch, & Varaiya, 2006). The paper presented a method to divide the total congestion into six components: congestion caused by incidents, special events, lane closures, adverse weather, the congestion that could be eliminated by ideal ramp metering, and the residual delay. The method was applied to a section of I-880 in the San Francisco Bay Area from January to June. The results of the study conclude that one-third of the congestion delay occurs at recurrent bottlenecks and could be potentially be eliminated by ideal ramp metering. Also, incidents and special events contribute to 18% of the delay, which can be reduced by more rapid detection and response, and information on DMSs.

A study for the Texas Department of Transportation examined ramp closures on freeways as part traffic management for incident management (Waller, Boyles, Fajardo, & Karoonsoontawong, 2007). The study examined incident severity as a measure to determine if a ramp closure should be considered. Microsimulation modeling was used to also look at ramp locations and ramp closure duration on effects of improving incident management.

Mei et al. conducted a research effort aimed at integrating wireless vehicular ad-hoc network (VANET) communication into a microscopic traffic simulation environment (Mei, Hu, Rouphail, & Lee, 2010). The simulation tools used for this study were DYNASMART-P, Aimsum, and Python, which emulated drivers' response to traffic messages distributed via VANETs. There were two networks involved in this study: the highway network and the VANET. Vehicles equipped with wireless communication capabilities move along the highway network and transmit data to other equipped vehicles, such as speed and location. There were two response types modeled in this study: Dynamic Route Diversion (DRD), which allows a driver to choose alternative paths to bypass an incident, and Variable Speed Limits (VSL), which minimizes abrupt decelerations due to reductions in roadway capacity. Eight scenarios were evaluated in this study, using different percentages of market penetration of equipped vehicles and incidents. The results of this study indicate that DRD or a combination of DRD and VSL is an effective way to alleviate congestion, but not VSL alone.

Improved Traveler Information

Richards and McDonald wrote a report evaluating the effectiveness of traffic information in an urban network by analyzing data from "real-life" case studies collected from seven locations in urban areas in the UK to assess driver response to DMS messages (Richards & McDonald, 2007). Traffic data was collected and analyzed for incidents occurring at each of the seven locations, and there were several key findings. For all case studies, there was evidence of drivers diverting in the event of an incident when an incident DMS message was displayed, but it was difficult to distinguish the effects of different information sources on the driver's behavior. The authors also concluded that there was not a conclusive correlation between incident severity and driver response, and the application of DMS in an urban area is likely to have only limited benefits.

Another research study evaluated the impact of DMS on toll road users in Orlando using a pre-deployment (one DMS) and a post-deployment (29 DMSs) survey analysis (Al-Deek, Vankata, & Flick, 2009). A detailed telephone survey was administered and modeling was performed to estimate the effects of DMS deployment on attitudes and behavior of toll road travelers. The study says that mitigating non recurring congestion on toll roads is more critical because commuters who make trips on these facilities tend to assume that the out of pocket cost will ensure these facilities will provide them with the least travel time when compared to other alternatives. The modeling in this research compared the role of DMS in the pre- and post-deployment overall satisfaction and diversion behavior of the toll road commuters. The results of the study showed that DMS helped some commuters make diversion decisions in the event of congestion, but overall satisfaction did not change significantly.

A study by Hu et al. used simulation to examine traveler information. This paper describes the proposed advanced traveler information evaluation method and the accompanying DYNASMART-P case study that modeled the capacity reduction due to work zone activities in the Research Triangle region in North Carolina, and the relative effectiveness of various ATIS scenarios (Hu, Williams, Rouphail, Khattak, & Zhou, 2009). The scenarios included a no work zone, no ATIS, existing ATIS, and two ATIS alternatives (20% and 30% ATIS). The results of the study concluded that as ATIS usage increased, the diversion rates increased, as drivers began to use alternate routes, the vehicles on the original route were reduced, and there were lower average travel and stop times. The study also presents a benefit-cost analysis to determine the value of the ATIS benefits on the one-year work zone activity (resurfacing).

Rathi et al. describe a 'closed-loop' framework that integrated two tools, MITSIMLab and DynaMIT, to assess the impact of dynamic route guidance disseminated through Dynamic Message Signs in response to simulated severe accidents (Rathi, Antoniou, Wen, Ben-Akiva, & Cusak, 2008). The case study is based on a freeway from lower Westchester County in New York, where drivers commonly experience heavy traffic conditions during commute periods. Two scenarios were modeled separately using NYSDOT data, and were representative of the frequent closures and bottlenecks that occur on this network. The results of the study concluded that using a DMS can significantly reduce the travel times due to incidents and non-recurrent congestion in general.

A Washington State study looked at a threshold-based method to replicate different scenarios using loop detector data on freeways and arterials in Bellevue, Washington, which can quantitatively capture en-route travelers' real-time decision on diversion and the diversion's impact on the alternative route

without the need for theoretical assumptions (Wu, Hallenbeck, & Wang, 2010). Two types of en-route travelers' diversion decisions were investigated: diversion on the freeway to the arterial when the en-route traveler observes congestion and concurrent diversion to the alternative arterial while the main arterial is impacted by freeway diversion. Performance measures, including freeway downstream occupancy, diversion rate, ramp occupancy, and arterial occupancy and volume were used to investigate the cause and effect of the diversion based on different levels of congestion. The results of this study concluded that travelers tend to seek an alternative route when freeway traffic suffers from high congestion, but travelers are less responsive to non-recurring ("unusual") congestion.

Improved Data Mining and Analysis

The research presented in the paper demonstrates how data mining can be used in deriving traffic diversion plans (Lee, Jeng, & Chandrasekar, 2002). According to the author, the ultimate goal of the traffic diversion plan under a non-recurring congestion situation is not only to divert the traffic to alleviate congestion, but also to control diverted traffic volumes effectively to prevent traffic breakdowns on alternative routes. The research mined and analyzed data generated from a simulation of an incident situation; and the results conclude that once an incident has occurred it takes more time to bring the traffic back to normal conditions. Therefore, timely action is necessary and alternative routes should be monitored closely while implementing the diversion plan.

The purpose of this research was to develop a model that can automatically learn emerging patterns in data to aid in the prediction of incident clearance times (Ozbay & Noyan, 2005). By assigning values from a real data set to the decision variables, incident patterns were extracted and a "possible world" for the duration prediction problem is created. In this study, dependency networks are generated from predictors that affect the incident clearance times. The models presented in this paper could eventually be used by "decision makers," including traffic engineers, TMC operators, or transportation planners.

A California study examined a methodology to develop analytical tools to enable CalTrans to better measure and predict non-recurrent congestion throughout the state (Dowling, Skabardonis, Carroll, & Wang, 2004). The researchers define non-recurrent congestion as the amount of delay to the traveling public that is caused by any of all of the following: incidents (including collisions, breakdowns, and debris), work zones, special events, and inclement weather. In order to compute non-recurrent congestion, one must subtract the amount of recurrent delay from total delay. Two methodologies were developed: the freeway Performance Measurement System (PeMS), which uses data from surveillance systems, and the recommended non-PeMS method, which is a more general and multipurpose method. There are several steps in the procedure for the application of the Non-PeMS Method, which are the selection of sample facilities/days, data collection and processing, estimating hourly demand for sample days, estimating capacity for sample facilities, computing recurrent delay, estimating incident-related delay (type, severity, and duration), estimating work-zone-related delay, computing weather delay, computing delay due to special events, and the extrapolation of results for quarterly, annual, and district totals.

Countermeasures for Congestion Caused by Weather

To address non-recurring congestion caused by weather, road weather management systems can provide information on the impact of weather events on the roadway system. The US Department of Transportation has sponsored the development of Clarus weather information system to reduce the impact of adverse weather events on the surface transportation system. Better weather information can be turned into traveler information to allow travelers to make informed decisions about travel decisions, mode choice, and route choice.

Countermeasures for Congestion Caused by Traffic Signal Timing

Incidents that cause non-recurring congestion on arterial streets are different than those on a freeway facility. A study conducted for the Texas Department of Transportation found that a single lane mid-block closure on an arterial street has a minor impact on roadway operations while a malfunctioning signal can have a dramatic impact (Short & Leudtke, 1994).

The study indicated that reducing the time to detect and respond to a signal malfunction could significantly reduce stops, delays, and fuel consumption. Reductions in detection and response times can be achieved with an effectively managed signal system. Other incidents such as railroad crossings, utility failures, and flooding that are not typically associated with freeways were also found to have significant impacts on arterial street operations. This is important to MAG because nearly two thirds of all travel in the MAG region occurs on arterials.

Adaptive signal control and other non-traditional solutions are another countermeasure being implemented in an attempt to improve signal system efficiencies, reduce congestion, enhance signal control responsiveness to incidents, and reduce signal re-timing costs. This paper presents the initial findings of a hardware-in-the-loop simulation (HILS) of ACTRA (time of day) and SCATS (adaptive) signal control on an eleven-intersection arterial section in Cobb County, Georgia (Hunter, Roe, & Wu, 2010). The initial findings indicate that during peak hours both control strategies provide similar performance, but at the hours bordering the peak hours, adaptive control (SCATS) provides control more tailored to the current conditions.

Countermeasures for Congestion Caused by Work Zones

Smart work zones (SWZs) are being deployed around the United States as a way to inform drivers dynamically about traffic conditions within a work zone. These systems provide real-time information to travelers, informing them about traffic and impacts such as lane closures or speed reductions in and around work zones. SWZs use sensors to detect traffic flow conditions on the work zone approaches. These data are then used to alert drivers of congestion or speed differentials in an effort to improve operations or safety. Agencies that are considering deploying SWZs are often faced with the challenge of trying to justify the cost of an SWZ system to decision makers who may be more inclined to use the funds for more traditional maintenance purposes. Although a number of states have evaluated SWZ systems, there has not been much effort to identify trends across multiple tests or extend those findings to predict likely impacts of proposed deployments.

According to an FHWA document, "nearly 25 percent of non-recurring freeway delay, or about 482 million hours, is attributed to work zones (Federal Highway Administration, 2007)." The study further states the successful deployment of technology to provide traveler information at work zones led to the following benefits:

- Between 50 and 85 percent of drivers surveyed said that they changed their route at least sometimes in response to travel time, delay or alternate route messages provided by work zone ITS.
- Simulation indicated that queue lengths could be reduced from 56 to 60 percent
- Simulation also indicated system-wide total delay could be reduced from 41 to 75 percent

A study in Michigan looked at speed management as a countermeasure to congestion in work zones. Static speed limits in work zones may not reflect current conditions, which can lead to low speed limit compliance and create high variance in vehicle speeds. A Michigan DOT 2003 study found that the speed limits displayed by VSL and operating speeds increased, driver compliance improves and more consistent speeds resulted.

Countermeasures for Congestion Caused by Special Events

The research presented from this study applied a variety of traffic management strategies to manage congestion resulting from football games at Montana State University in Bozeman, Montana in 2007 (Lassacher, Veneziano, Albert, & Ye, 2009). A traffic management plan was developed for MSU home football games and incorporated several congestion mitigation strategies, such as real-time traveler information from DMS signs and public outreach programs, closures of roads that are not suited for heavy traffic volumes, traffic signal timing, and real-time traffic monitoring. The results of the study concluded that several types of strategies, such as signal retiming and manual traffic control, could be successfully applied in a rural community to manage congestion from planned special events. The study also found that inter-agency cooperation was essential to the success of this research.

A special event can cause non-recurring congestion and requires additional traffic management strategies. Another study investigated and evaluated manual traffic control at all-way, stop-controlled intersections during special events (Ye, Veneziano, & Lassacher, 2009). It first uses a simulation method to investigate saturation flow rate under manual operation. This method was then applied to field data collected at a special event in Bozeman, Montana to evaluate manual traffic control. The results of the study found that the signal length of manual operation was longer than what optimized signal timing should be, which demonstrated that the simulation method is useful in determining more effective traffic management strategies. The study also concluded that in order to develop a better manual control timing plan during special events, inter-agency cooperation is key, including the police department, the organization responsible for the special event, and the entities responsible for managing the roadway.

ATTACHMENT A:

References

Al-Deek, H., Vankata, S., & Flick, J. (2009). The Impact of Dynamic Message Signs on Satisfaction and Diversion of Toll Road Travelers. *Transportation Research Board 2009 Annual Meeting.* Washington, D.C.

Chin, S. M., Franzese, O., Greene, D. L., & Hwang, H. L. (2002). *Temporary Losses of Highway Capacity and Impacts on Performance.* Oak Ridge, TN: Oak Ridge National Laboratory with R.C. Gibson or the University of Tennessee.

Chitturi, M. V., Benekohal, R., & Kaja-Mohideen, A.-Z. (2008). Methodology for Computing Delay and Users Costs in Work Zones. *Transportation Research Board 2008 Annual Meeting.* Washington, D.C.

Cunard, R. A. (2000). Incident Management Programs in the United States. *Proceedings of the Conference Road Safety on Three Continents*, (pp. 499-514). Pretoria, South Africa.

Dailey, D. J. (2006). *The Use of Weather Data to Predict Non-recurring Traffic Congestion.* Seattle: Transportation Northwest Regional Center X (TransNow).

Dowling, R., Skabardonis, A., Carroll, M., & Wang, Z. (2004). Mothodology for Measuring Recurrent and Nonrecurrent Congeston. *Transportation Research Record , 1867*, 60-68.

Federal Highway Administration. (2007). *Intelligent Transportation Systems for Work Zones.* Washington, D.C.: Federal Highway Administration, US Department of Transportation.

Hallenbeck, M. E., Ishimaru, J. M., & Nee, J. (2003). *Measurement of Recurring Versus Non-Recurring Congestion.* Seattle, WA: Washington State Transportation Center.

Hallenbeck, M. E., Ishimaru, J. M., & Nee, J. (2003). *Measurement of Recurring Versus Non-Recurring Congestion: Technical Report.* Seattle, WA: Washington State Transportation Center.

Hardy, M. H., & Higginbotham, B. (2008). Quantifying the Contributing Factors of Traffic Congestion Using the Urban Congestion Report Data. *Transportation ReEsearch Board 2008 Annual Meeting.* Washington, D.C.

Heath, A. J., & Turochy, R. E. (2009). Development of a Range-Based Method to Estimate Mobility Benefits of Freeway Service Patrols and Its Application in Alabama. *Transportation Research Board 2009 Annual Meeting.* Washington, D.C.

Hu, H., Williams, B. M., Rouphail, N., Khattak, A., & Zhou, X. (2009). Modeling the Role Transportation Information in Mitigating Major Capacity Reduction in a Regional Network. *Transportation Research Board 2009 Annual Meeting.* Washington, D.C.

Hunter, M. P., Roe, M., & Wu, S. K. (2010). Hardware-in-the-Loop Simulation Evaluation of Adaptive Signal Control. *Transportation Research Board 2010 Annual Meeting.* Washington, D.C.

Kopf, J. M., Nee, J., Ishimaru, J. M., & Hallenbeck, M. E. (2005). *Measurement of Recurring and Non-Recurring Congestion: Phase 2.* Seattle, WA: Washington State Transportation Center.

Kwon, J., Mauch, M., & Varaiya, P. (2006). The Components of Congestion: Delay from Incidents, Special EVents, Lane Closures, Potental Ramp Metering Gain, and Excess Demand. *85th Annual Meeting of the Transportation Research Board.* Washington, D.C.

Lassacher, S., Veneziano, D., Albert, S., & Ye, Z. (2009). Special Event Traffic Management in Small Communities. *Transportation Research Board 2009 Annual Meeting.* Washington, D.C.

Lee, D.-H., Jeng, S.-T., & Chandrasekar, P. (2002). Application of Data Mining in Developing Traffic Diversion Plans. *Proceedings for the 9th World Congress on Intelligent Transportation Systems (ITS America).* Chicago.

Mei, B., Hu, H., Rouphail, N. M., & Lee, J.-j. (2010). A Simulation Model for Studying the Impact of V2V Wireless Communications on Traffic Network Operations. *Transportation Research Board 2010 Annual Meeting.* Washington, D.C.

Michigan Department of Transportation and Michigan State University. (2003). *Field Test of Variable Speed Limits in Work Zones (In Michigan), Final Report.* Lansing, MI.

Ozbay, K., & Noyan, N. (2005). Estimation of Incident Clearance TImes using Bayesian Networks Approach. *Accident Analysis and Prevention* , 542-555.

Pisarski, A. (2007). *Commuting in America III, NCHRP Report 550, TCRP Report 110.* Washington, D.C.: Transportation Research Board.

Rathi, V., Antoniou, C., Wen, Y., Ben-Akiva, M., & Cusak, M. (2008). Assessment of the Impact of Dynamic Prediction-Based Route Guidance using a Simulation-Based, Closed-Loop Framework. *Transportation Research Board 2008 Annual Meeting.* Washington, D.C.

Raub, R. A. (1999). Limiting the Effects of Incidents on Urban Arterial Roadways. *World Transport Research: proceedings of the 8th World Conference on Transport Research*, (pp. 395-407). Antwerp, Belgium.

Recker, W., Golob, T., & Yazdan, F. (2007). *CalTrans Research Notes: Development of a Tool for Measuring Non-recurrent Congestion Impacts of Accidents.* Irvine, CA: CalTrans.

Rensselaer Plytechnic Institute. (2007). *Quantifying Non-Recurring Delay on New York City's Arterial Highways.*

Richards, A., & McDonald, M. (2007). Investigating the Limits of the Benefits Provided by VMS in an Urban Network. *Transportation Research Board 2007 Annual Meeting.* Washington, D.C.

Short, J. T., & Leudtke, P. M. (1994). User Benefits from an Arterial Incident Detection and Response System. *1994 ITE Annual Meeting and Compendium of Technical Papers*, (pp. 523-527).

Schrank, D., and T. Lomax (2009). 2009 Urban Mobility Report. Texas Transportation Institute. College Station, Texas.

Skabardonis, A., Petty, K. F., Bertini, R. L., Varaiya, P. P., Noeimi, H., & Rydzewski, D. (1997). I-880 Field Experiment: Analysis of Incident Data, Paper No. 970121. *Transportation Research Record , 1603*, 72-79.

Skabardonis, A., Varaiya, P., & Petty, K. F. (2003). Measuring Recurrent and Nonrecurrent Traffic Congestion, Paper No. 03-4261. *Transportation Research Record , 1603*, 119-124.

TCRP Synthesis 73. (2008). *AVL Systems for Bus Transit: Update A Synthesis of Transit Practice.* Washington, D.C.: Transportation Research Board.

Transportation Research Board . (n.d.). *Research in Progress*. Retrieved July 26, 2009, from Arizona VII Initiative: Proof of Concept/Operational Testin: http://rip.trb.org/browse/dproject.asp?n=14986

Waller, S. T., Boyles, S., Fajardo, D., & Karoonsoontawong, A. (2007). *Ramp Closure Strategies for Incident Management.* Austin: Center for Transportation Research .

Washington State Department of Transportation. *The Causes of Congestion.* Seattle, WA.: WSDOT.

Wu, Y.-J., Hallenbeck, M. E., & Wang, Y. (2010). Impacts of Freeway Traffic Congestion on En-route Traveler's DIversion. *Transportation Research Board 2010 Annual Meeting.* Washington, D.C.

Xu, C., Wang, W., Chen, J., Wang, W., Yang, C., & Li, Z. (2010). Using Structural Equation Modeling to Analyze Travelers. *2010 Transportation Research Board Annual Meeting.* Washington, D.C.

Ye, Z., Veneziano, D., & Lassacher, S. (2009). Analysis of Manual Traffic Control at All-Way Stop-Controlled Intersections During Special Events. *Transportation Research Board 2009 Annual Meeting.* Washington, D.C.

Zhan, C., Gan, A., & Hadi, M. (2006). Analyzing Freeway Service Patrol Data. *Application of Advanced Technology in Transportation* (pp. 304-309). Chicago: American Society of Civil Engineers.

Zhou, H., Hagen, L., Singh, H., & Clark, P. (2006). Benefit and Cost Analysis of the Road Ranger Program in Florida. *2006 ITE Annual Meeting and Exhibit Compenium of Technical Papers.* Milwaukee, WI: Institute of Transportation Engineers.

ATTACHMENT B:

Taxonomy

Typical Day	a weekday that exhibits travel patterns which occur on a regular basis; standard practice is to collect data on Tuesdays, Wednesdays, and Thursdays of weeks without holidays or other occurrences that may influence travel patterns.
AADT (Annual Average Daily Traffic)	the total volume of traffic passing a point or segment of a highway in both directions for one year divided by the number of days in the year.
Access Management	a control of movement onto highways. Strategies include restricting the intersections and interchanges of other streets and highways, restricting or limiting the number of driveways or controlling these entrance points in some manner, as with traffic signs or signals.
AM peak	the morning time period when traffic volumes are highest; also referred to as “morning rush hour”; it can often be more than 60 minutes in length; typically falls between 7:00 and 9:00AM in the Phoenix region.
Arterial	a signalized street that primarily serves through-traffic and that secondarily provides access to abutting properties, with signal spacing of 2.0 miles or less.
Auto Occupancy	the number of persons per automobile, including the driver.
Average Daily Traffic (ADT)	the average number of vehicles per day traveling in either direction on a roadway based on traffic volumes collected over a number of days greater than one but less than a year.
Average Travel Speed	the length of a highway segment divided by the time it takes to traverse that segment, including all delays is the calculation for a weighted average of speed.
Before and After Study	a study undertaken to determine the effects of an implemented project, program, or policy change; performance measures are assessed before and after implementation to measure impacts; costs can also be taken into account and compared to

	benefits in order to gauge cost-effectiveness of the solution.
Benefit Cost Ratio (BCR)	the ratio of a project's present value benefits to its present value costs. The BCR is useful for comparing projects of different scale or financial size since it assesses economic efficiency.
Bluetooth	a proprietary open wireless protocol for exchanging data over short distances (using short length radio waves) from fixed and mobile devices, creating personal area networks (PANs). It provides a secure way to connect and exchange information between devices such as faxes, mobile phones, telephones, laptops, personal computers, printers, Global Positioning Systems (GPS) receivers, digital cameras, and video game consoles.
Bottleneck	physical or geometric features of a street or freeway that reduce the facility's capacity (or ability to accommodate traffic flow) as compared to other locations on the same facility.
Buffer Time Index	a measure of reliability, or more appropriately, *un*reliability. It is the additional time that must be added to average travel time to ensure on-time arrival with 95% certainty.
Buildout	the maximum amount of housing and jobs that can fit within the current zoning.
Calibration	the process of comparing model parameters with real-world data to ensure that the model realistically represents the traffic environment. The objective is to minimize the discrepancy between model results and measurements or observations**.**
Capacity	the maximum number of vehicles that can reasonably be expected to pass over a lane or a roadway during a given time period under prevailing roadway and traffic conditions. The capacity is based on a variety of factors including lane and shoulder widths, vehicle types, roadway grades, etc. Typically, the maximum expressway capacity for automobiles is 2,000 vehicles per lane per hour. The capacity of a roadway can change

	because of weather, work zones, or traffic incidents.
Capital Costs	Nonrecurring or infrequently recurring costs of long-term assets, such as land, guideways, stations, buildings, and vehicles. These costs often include related expenses, for example, depreciation and property taxes. See also *operating costs*.
Capital Improvement Program	a multi-year plan created by an agency/jurisdiction to schedule major improvements and sources of funds to pay for those improvements. See also Transportation Improvement Program.
Carpool	an arrangement in which at least two people (for facilities in the Phoenix metro area) share the use, cost, or both of traveling in privately owned automobiles between fixed points on a regular basis. See also vanpool.
Central Business District (CBD)	the commercial heart of a city. The CBD or downtown is the central district of a city, usually typified by a concentration of retail and commercial buildings. Although applicable to any city, both terms usually refer to larger cities.
Channelization	roadway facilities that accommodate turning movements. Typical examples are left and right turn pockets at an intersection.
Closed-Circuit Television (CCTV)	cameras used to view roadway conditions.
CMP (Congestion Management Process)	a federally mandated program within metropolitan planning areas to evaluate and develop transportation strategies and plans for addressing existing and future traffic congestion.
Collector	a type of roadway that connects traffic from local roads and to arterials. Collectors have lower speed and carry lower levels of traffic than arterials.
Compressed Work Week	an alternative work schedule, in accordance with employer policy, that regularly allows a full- time employee to eliminate at least one work day every two weeks by working longer hours during the

	remaining days, resulting in fewer commute trips by the employee.
Congested Travel (%)	the congested peak period vehicle-miles of travel (VMT) divided by total VMT in the peak period. This is a relative measure of the amount of peak period travel affected by congestion.
Congestion	a condition which does not permit movement on a transportation facility at optimal legal speeds and is characterized by unstable traffic flows. Traffic demands vary significantly depending on the season of the year, the day of the week, and even the time of day.
Congestion (Non-Recurring)	condition of overcrowding on a roadway caused by actions such as special events and/or traffic accidents, manifested by high densities, low speeds, stop-and-go driving, and increased delay. The capacity of a roadway, often mistaken as constant, can change because of weather, work zones, or traffic incidents.
Congestion gauge	volume to Capacity ratio on congested roadways.
Congestion Mitigation and Air Quality Improvement Program (CMAQ)	a categorical funding program created under the Intermodal Surface Transportation Efficiency Act. It directs funding to projects that contribute to meeting national air quality standards.
Congestion (Recurrent)	condition of overcrowding on a roadway caused by demand exceeding capacity, manifested by high densities, low speeds, stop-and-go driving, increased delay and high rate of rear-end collisions occurring upstream of the bottleneck.
Ramp Meter	a form of entrance ramp control used to reduce freeway congestion by managing vehicle flow from arterial-to-freeway connectors. The connector contains a traffic signal that regulates the flow of vehicles on to the mainline freeway.
Corridor Control	a system designed to improve travel flow through freeway corridors by applying traffic management strategies and control measures to travel corridors

	that can encompass several freeways and arterial streets.
Corridor	a broad geographical band that follows a general directional flow or connects major sources of trips. It may contain a number of streets and highways and transit lines and routes.
Corridor Studies	study with a focus on a segment of a particular travel corridor or travel shed. Land use, access issues, capacity, level of service, geometrics, and safety concerns are studied; alternatives are analyzed and recommendations are made. Corridor studies are usually prepared with the participation and cooperation of the affected communities and governmental agencies. Recommendations for improvements are often incorporated into the local comprehensive plans of the participating cities and continue to be used by implementing agencies as improvements in the corridor are made.
Crash Rate	the frequency with which traffic accidents have occurred along a defined roadway segment over a defined period of time.
Criterion / Criteria	measures or factors used in the development or in the decision-making process for a transportation improvement.
Cut-Through Traffic	traffic that uses the local street system in an unintended manner to circumvent congested intersections or corridors.
Delay per Vehicle per Mile	Delay per Vehicle divided by the length of the roadway segment; this performance measure is used to facilitate the comparison of unequal roadway segments.
Delay	the amount of time it takes to traverse a given roadway segment minus the amount of time it would take to traverse that roadway segment at the posted speed limit if there were no interference. The additional travel time experienced by a driver or passenger beyond what would reasonably be desired for a given trip.

Demand	the number of vehicles desiring to use a given segment of roadway during a specified unit of time.
Density	the number of vehicles occupying a given length of a lane or roadway usually expressed in vehicles per mile.
Detector Loops	a component imbedded in the pavement and used to detect and classify the type of vehicles passing over them. The loops are linked to the lane controller and can be used individually to count traffic or to trigger the violation enforcement cameras or in tandem to measure vehicle speeds.
Downstream	the direction in which traffic flow is moving.
Driver Information Systems	communication systems designed to provide motorists with the most recent information regarding freeway operating conditions.
Duration of Congestion	a measurement of the span of time during which a roadway segment would be considered congested. This is generally not directly measured and reported, but is imbedded in such overall congestion metrics as vehicle hours of delay and person hours of delay.
Dynamic Message Sign (DMS)	electronic signage that employs ITS technology and centralized control systems to change messages in real time, providing motorists with timely and useful information; see also Variable Message Sign (VMS)
Economic Rate of Return (ERR)	the economic rate of return, sometimes referred to as the internal rate of return, gives the effective discount rate for which the project's benefits would just equal its costs, in present value terms. In other words, it is the discount rate that yields a BCR of 1.0.
Elasticity of Demand	a measure of the sensitivity of demand for a commodity to a change in its price. It equals the percentage change in consumption of the commodity that results from a one-percent change in its price. The greater the elasticity, the more price-sensitive the demand for the commodity.

	Price elasticity is an important indicator of the effects of pricing strategies.
Extent of Congestion	the maximum geographic extent of congestion on transportation system at any one time.
FHWA (Federal Highway Administration)	an agency of the US Department of Transportation responsible for funding highways, trails, and ferries.
Financial Constraint	the total estimated costs of projects included in a transportation plan cannot exceed estimated revenues and the estimated cost of constructing, operating, and maintaining the total (existing plus planned) transportation system over the period of the plan.
Fixed Cost	a cost that remains relatively constant irrespective of the level of operational activity; expenditures that do not vary with output. Examples include land, guideways and rent.
Flex-Time	an employer policy allowing individual employees some flexibility in choosing the time, but not the number, of their working hours.
Forecast	a future projection of traffic volumes based on expected future land use patterns and population estimates.
Free Flow	a state of the traffic flow at which motorists can maintain their desired speed with little or no delay since congestion is not present.
Freeway Management Strategies (FMS)	operational improvements designed to maximize traffic flow for all vehicles using the freeway.
FTA (Federal Transit Administration)	an agency of the US Department of Transportation responsible for funding transit systems. (They were formerly the Urban Mass Transit Administration.)
Functional Classification	classification of roadways according to their primary function-mobility for through trips or access to adjacent lands. A four-class system is used to designate roads (principal arterials, minor arterials, collectors, local streets).

General-Purpose Lanes — freeway lanes that are open for use by all vehicles (e.g., trucks, HOVs, single occupant vehicles).

Generated Traffic — additional vehicle trips on a particular roadway or area that occur when roadway capacity is increased or travel conditions are improved, due to latent demand (additional trips that travelers would make if traffic conditions were improved). A portion of generated traffic often consists of *induced travel*, that is, an increase in total vehicle mileage (which excludes travel shifted from other times and routes).

Geographic Information System — a computer-based system that links the geographic location of map features to text information or databases.

Geometric Condition — the special characteristics of a facility, including approach grade, the number and with of lanes, lane use, and parking lanes.

Geometric Delay — the component of delay that results when geometric features cause vehicles to reduce their speed in negotiating a facility.

Grade Crossing — a crossing or intersection of roadways, railroad tracks, pedestrian walks, or combinations of these at the same level or grade.

Grade Separated — a crossing of roadways, railroad tracks, pedestrian walks, or combinations of these that do not intersect. Overpasses, underpasses, and bridge structures are common examples.

Growth Factor — a percentage increase applied to current traffic demands to estimate future demands.

High Occupancy Vehicle (HOV) — **typically,** vehicles carrying two or more persons per vehicle. HOVs can include cars, vans, buses, trucks, or other vehicles that meet the desired occupancy requirement.

High-Occupancy Vehicle (HOV) Lanes — highway lanes reserved for vehicle carrying two or more people. (The specific number of people in the vehicle or class of vehicles who can use this facility is established locally.) These lanes are

	officially denoted with a diamond marking and are sometimes called “diamond lanes.”
Highway Advisory Radio (HAR)	systems designed to broadcast information on traffic conditions in a particular area to motorists traveling in that area and who have immediate need for the information. Motorists are informed through freeway signs that they can access the broadcast via designated frequencies on their car radios.
Ideal Travel Time	the amount of time it would take to traverse a given roadway segment at the posted speed limit if there were no interference.
Incident	any occurrence on a roadway that impedes the normal flow of traffic.
Incident Delay	the component of delay that results from an incident, compared with the no-incident condition.
Incident Management	managing forms of non-recurring congestion, such as spills, collisions, immobile vehicles, or any other impediment to smooth, continuous flow of traffic on freeways.
Infrastructure	the basic facilities, services, and installations needed for the functioning of a community or society, such as transportation and communications systems, water and power lines, and public institutions including schools, post offices, and prisons.
Integrated Traffic Management System	the development and application of network-wide data collection and sharing of traffic information system. The system can integrate data and control systems from freeways, arterials and city streets to provide real-time proactive traffic information and control. Implementation of the system would facilitate congestion management over the entire network across multi-jurisdictional boundaries. The system could provide incident detection, transit and emergency vehicle priority, and advance traveler information.

Intelligent Transportation System (ITS)	the development or application of technology (electronics, communications, or information processing) to improve the efficiency and safety of surface transportation systems.
Intensity of Congestion	a measurement of the severity of congestion during its peak hour. Intensity is typically measured by such factors as peak hour level of service, peak hour volume-to-capacity (V/C) ratio, and peak hour speed.
Lane Controller	a micro processor ETC component that coordinates the activities of all equipment in a single lane and generates the transactions assigned to individual customers using that lane.
Lane-Miles of Congestion	a measure that reflects mobility of a facility or a section of a facility. It indicates the road space that functions at less than free-flow speeds during the peak. It compares actual roadway volume with maximum acceptable volume for that roadway.
Latent Demand	the total number of potential users desiring to use a facility (street or freeway) at a given point.
Level of Service	as related to highways, the different operating conditions that occur on a lane or roadway when accommodating various traffic volumes. It is a qualitative measure of the effect of traffic flow factors, such as speed and travel time, interruption, freedom to maneuver, driver comfort and convenience, and indirectly, safety, and operating costs. It is expressed as levels-of-service A through F. Level A is a condition of free traffic flow where there is little or no restriction in speed or maneuverability caused by presence of other vehicles. Level F is forced-flow operation at low speed with many stoppages, with the highway acting as a storage area.
Life-Cycle Maintenance	concept of keeping a facility useable at least through its design life by conducting scheduled maintenance.

Light Rail Transit (LRT)	an electrically propelled vehicle operated singly or in trains on predominantly reserved, but not necessarily grade-separated, rights-of-way.
Major Construction	roadway improvements that increase the operational characteristics of a highway facility, including decreasing congestion, increasing operating speed and reducing accidents.
Managed Lane	a lane or lanes designed and operated to achieve stated goals by managing access via user group, pricing, or other criteria. A managed lane facility typically provides improved travel conditions to eligible users.
Media Access Control (MAC)	an electronic identifier, or tag, in a Bluetooth device. The MAC address serves as an electronic nickname for each electronic device in data communication. The MAC address is unique for each Bluetooth device.
Metering	the concept of regulating the amount of traffic that can enter into a downstream lane or freeway facility.
Meters	signals on freeway ramps that smooth traffic flow to increase road capacity. Some metered ramps have bypasses for buses and carpools.
Metropolitan Planning Organization (MPO)	federally mandated regional organizations responsible for comprehensive transportation planning and programming for in urbanized areas.
Mitigation	the specific improvements made to a roadway or intersection to bring a deficient facility back or below the minimum standard.
Mixed Flow Lanes	see general-purpose lanes.
Mobility	the ability of a person or people to travel from one place to another.
Mode	a particular form of travel (e.g., walking, traveling by automobile, traveling by bus or traveling by train).

Model	a mathematical description of a real-life situation that uses data on past and present conditions to make a projection about the future. It is used for analysis of the system or its evaluation under various conditions.
Multimodal	concerning or involving more than one transportation mode.
Multimodal Link	the connection between two or more passenger transportation methods (such as bicycle, walking, automobile and transit).
Network	1. In planning, a computerized system of links and nodes that describes a transportation system. 2. In highway engineering, the configuration of roadway that constitutes the total system. 3. In transit operations, a system of transit lines or routes, usually designed for coordinated operation.
Node	a defined point along a roadway corridor that marks the beginning and/or end of a segment.
Non-Motorized	generally referring to bicycle, pedestrian and other modes of transportation not involving a motor vehicle.
Non-Recurring Congestion (defined under Congestion as well)	congestion caused by atypical events such as highway accidents, sudden lane or road closures, weather conditions, or sudden traffic demand increases induced by a special event such as a football game. Non-recurring congestion can occur at anytime, including midday, overnight, weekends, and also during peak periods, in addition to recurring traffic.
Off-Peak Period	times of day outside the peak periods.
Operating Costs	the sum of all recurring costs (e.g., labor, fuel) that can be associated with the operation and maintenance of the system during the period under consideration.
Operational Improvement	a capital improvement consisting of installation of traffic surveillance and control equipment,

	computerized signal systems, motorist information systems, integrated traffic control systems, incident management programs, and transportation demand and system management facilities, strategies and program.
Park-and-Ride	an access mode to transit and other HOV modes in which patrons drive private automobiles or ride bicycles to a transit station, stop, or carpool/vanpool waiting area and park the vehicle in the area provided for that purpose (park- and-ride lots, park-and-pool lots, commuter parking lots, bicycle rack or locker).
Parking Utilization	a measurement the degree of use of the available parking. A high utilization percentage means that few spaces are available.
PDO (Property Damage Only) Crash	a reportable crash that did not result in any fatalities or notable injuries.
Peak Hour	the single hour of the day which the maximum amount of travel occurs. Usually defined by identifying the highest of four consecutive 15 minute traffic counts along primary roadways.
Peak Hour Volume	the volume of traffic passing a point or segment of a highway during the busiest hour of a typical day or peak period.
Peak Period	the period of the day during which the maximum amount of travel occurs. It may be specified as the morning (a.m.) or afternoon or evening (p.m.) peak. Usually from 6:00-9:00 AM or 4:00-7:00 PM.
Percent Congested Travel	the congested peak period vehicle-miles of travel (VMT) divided by total VMT in the peak period. This is a relative measure of the amount of peak period travel affected by congestion.
Performance Measures	objective measurements and observations to determine the degree of success a project, program, or initiative has had in achieving its stated goals and objectives.

Person Hours of Delay (PHD)	calculated by multiplying VHD by the average vehicle occupancy rate. This reflects the fact that vehicle occupancy differs from place to place, and that the number of people affected by one vehicle hour of delay may vary.
Person-Trip	trip made by a person from one location to another whether as a driver, passenger or pedestrian.
Planning Time Index	a ratio of the total time needed to ensure 95% on-time arrival as compared to a free-flow travel time. For example, a value of 40% means that a traveler should budget an additional 8 minute buffer for a 20-minute average peak trip time to ensure 95% on-time arrival.
PM Peak	the afternoon/evening time period when traffic volumes are highest; also referred to as "evening rush hour"; it can often be more than 60 minutes in length; typically falls between 4:00 and 7:00 PM in the Phoenix region.
Preferential Access	an advantage offered to a group of users allowing rideshare vehicles and buses to access roadways faster than other vehicles by bypassing metered ramps.
Preservation	preservation activities are directed toward the elimination of deficiencies and major cost replacement of existing facilities. Preservation is not meant to include work that will increase the level of service by the addition of traffic lanes.
Principal Arterial	a major surface street with relatively long trips between major points and with through-trips entering, leaving, and passing through an urban area.
Programmed Improvements	projects found in the Transportation Improvement Program. See Transportation Improvement Program.
Public Transportation	transportation service by bus, rail, paratransit, van, airplane or ship, offered by an operator on a regular basis to the general public.

Qualitative Analysis	a general concept which categorizes a process used in certain types of environmental or route location studies where multiple factors are compared in a systematic and comprehensive manner on the basis of sound judgment. Factors analyzed by using a qualitative analysis are such that they cannot be measured in monetary terms, have no apparent common denominators, and are not readily quantifiable.
Quantitative Analysis	the process used in certain economic, cost-benefit, engineering, or traffic studies where multiple factors, elements, and/or outcomes are evaluated and compared by the use of measurable data. Certain mathematical models, formulas, numerical indices, rankings, and value matrices may be used to assist with such a process.
Queue	a line of vehicles, bicycles, or persons waiting to be served by the system in which the flow rate from the front of the queue determines the average speed within the queue. Slowly moving vehicles or people joining the rear of the queue are usually considered part of the queue. The internal queue dynamics can involve starts and stops. Faster-moving line of vehicles is often referred to as a moving queue of a platoon.
Ramp Metering	a form of entrance ramp control used to reduce freeway congestion by managing vehicle flow from arterial on-ramps. An on-ramp contains a traffic signal that regulates the entry of vehicles onto the freeway.
Real-Time Control	the processing of information or data in a sufficiently rapid manner so that the results of the processing are available in time to influence the process being monitored or controlled.
Recurring Congestion	congestion caused by the predictable daily increase in peak period traffic demand; because the capacity of the roadway system is generally fixed, an increase in demand will result in an increase in congestion. This type of congestion typically occurs during the weekday AM and PM peak periods, and is generally caused by large numbers of commuters

	traveling between their workplaces and homes, particularly during the AM peak period. Recurring congestion can also occur on weekends, particularly in area with significant retail or recreational activity. Recurring congestion can also be seasonal in nature, particularly in relation to holidays and recreation destinations.
Rehabilitation	**r**oadway improvements intended to correct conditions identified as deficient without major changes to the cross section. These projects should consist of removal and replacement of base and pavement, shouldering and widening and drainage correction as needed.
Revenue Neutral	revenue-neutral pricing strategies involve rebating some or all of the revenue generated by pricing to toll payers, where generating revenue is not an objective of value pricing.
Reverse-Commute Transit	transit from residence to an employment location in a direction opposite to the heaviest flow of traffic. In this region, primarily from the central city to a suburb.
Reversible Flow	lanes than can be operated in reverse direction to reduce congestion during certain peak periods.
Ridesharing	the function of sharing a ride with other passengers in other vehicles. The term is usually applied to carpools and vanpools.
Road Pricing	an umbrella phrase that covers all charges imposed on those who use roadways. The term includes such traditional revenue sources as fuel taxes and license fees as well as charges that vary with time of day, the specific road used, and vehicle size and weight.
Roadway Section	a roadway section is a cross-section of a roadway which displays, travel lanes, turning lanes, bike lanes, sidewalks, and medians with their respective dimensions. Each classification of roadway has a corresponding roadway section.

Roadway Standards — the standards set by the governing agency for the construction of roadway and related improvements.

Routine Maintenance — roadway maintenance consisting of sweeping, periodic applications of bituminous overlays, seal treatments, milling, crack routing and filling and base repair. These treatments are intended to help ensure the roadway can be used to the end of its design life. These projects are ineligible for federal funding.

SAFETEA-LU (Safe, Accountable, Flexible, Efficient Transportation Equity Act: A Legacy for Users) — federal legislation authorizing highway, safety, transit and other surface transportation programs from 2005 through 2009; maintained many initiatives from ISTEA and TEA-21 with increased emphasis on certain areas such as highway safety.

Segment — the portion of a highway corridor between two defined points.

Severity Index — a weighted measure of the relative economic cost to society of the injuries and fatalities related to traffic crashes along a defined roadway segment.

Signal Preemption — an interruption of the normal operation of a signal in order to immediately serve a particular movement. Is typically utilized by emergency vehicles to expedite travel.

Single-Occupant Vehicle (SOV) — a motor vehicle occupied by the driver only.

Spot Speed — the speed of a vehicle at a particular moment in time; different from average speed because it is a snapshot of a particular moment rather than speed over a certain distance.

Sprawl — dispersed, auto-dependent development outside of compact urban and village centers, along highways, and in rural countryside.

Stable Flow — levels of service A through E are representative of stable flow. It is characterized by the low density-high speed sides of the flow, speed, density curves.

Stakeholders	individuals and organizations involved in or affected by the transportation planning process. Include federal/state/local officials, MPOs, transit operators, freight companies, shippers, and the general public.
State Implementation Plan (SIP)	a federally required planning document prepared and maintained by the Minnesota Pollution Control Agency. It identifies state actions and programs to implement designated responsibilities under the Clean Air Act.
Steering Committee	a selected group of citizens that are appointed to participate in the development and review of a planning document.
Street Design Guidelines	standards for the design of a roadway including the width, shoulder area, and subsurface material. See also roadway standards.
Surface Transportation Program (STP)	program which made funds available for a broad range of highway, mass transit, safety and environmental purposes. STP funds could be used for highway construction and 4R; bridge projects; transit capital projects; carpool, parking, bicycle and pedestrian facilities; highway and transit safety improvements; traffic monitoring, management and control facilities; transportation control measures; and wetland mitigation efforts.
Surveillance	the monitoring of traffic performance and control system operation.
Telecommuting	the elimination or reduction in commuter trips by routinely working part of full-time at home or at a satellite work station closer to home.
Throughput	the amount of vehicles/persons that can pass a point on a roadway or pass through an intersection over a specified period of time. Throughput can be equated to capacity if considering vehicles alone.
Time Mean Speed	**the arithmetic mean of the speed of vehicles passing a point during a given time interval (see related Spot Speed)**

Total Delay	delay per vehicle multiplied by the peak hour volume in that roadway segment; expressed in vehicle-hours; this performance measure facilitates the comparison of corridors by considering the number of vehicles impacted by the congestion (e.g., Corridor A and Corridor B both have 5 minutes of delay per vehicle; however, Corridor A impacts 100 vehicles and Corridor B impacts 1,000 vehicles, suggesting Corridor B is a more significant problem).
Traffic Calming	techniques such as speed bumps and tables, narrowed lanes, and traffic roundabouts used to slow traffic in or divert through traffic out of primarily residential neighborhoods.
Traffic Model	a traffic model is a tool for representing and analyzing the major ways people get around. Usually this tool is a software package which incorporates a road network, land use data, and a mathematical formula to distribute and route trips. The model is calibrated to existing traffic counts. Then it can be used to forecast traffic and test the effect of changes in the road network.
Traffic or Transportation Analysis Zone (TAZ)	a subdivision of the project (or study) area for which demographic data are collected in order to estimate traffic volume. The arrival and departure pattern of the estimated traffic is also organized by TAZs.
Transportation Control Measure (TCM)	a measure intended to reduce pollutant emissions from motor vehicles. Examples of TCMs include programs to encourage ridesharing or public transit usage, and city or county trip-reduction ordinances. As a marginal air quality non-attainment area, the Capital District is not required to implement TCMs, but is in practice, voluntarily implementing many such programs.
Transportation Demand Management (TDM)	actions that improve transportation system efficiency by altering transportation system demand using such strategies and facilities as: pricing, ridesharing; park-and-ride facilities, transit friendly development / zoning; and employer-based programs—such as staggered work hours

	and telecommuting. TDM programs improve the efficiency of existing facilities by changing demand patterns rather than embarking on capital improvements.
Transportation Demand	the quantity (of transportation) desired by users.
Transportation Improvement Program (TIP)	defined in federal regulation as..."A staged multi-year program of transportation projects for a metropolitan planning area, excluding planning and research activities." A spending plan for federal funding expected to flow to the region from all sources for transportation projects of all types.
Transportation Management Area (TMA)	as defined by TEA-21, a TMA is designated by the Secretary of Transportation for all urbanized areas over 200,000 with boundaries contiguous to that of the MPO. TMAs must include a congestion management system (CMS) in their planning process and are responsible for project selection under the STP program.
Transportation Management Association (TMA)	voluntary groups set up to manage and reduce the number of trips taken in an area. TMAs are often begun by employers in heavily congested corridors. TMAs are considered a benefit to employees to help relieve the stress of daily commuting.
Transportation System Management (TSM)	integrated protocols and computerized ITS systems used to manage roadway and transit facilities. TSM techniques improve system capacity without physical expansion or behavioral changes. Typical TSM measures involve continuous management and operation of traffic systems, and utilize integrated traffic control systems, incident management programs, and traffic control centers.
Transportation System Management Strategies (TSMS)	low-cost, easily implemented programs and methods to improve the efficiency and effective capacity of the existing transportation system. Typical TSM techniques can include installation of new traffic signals, creating new signal phases or phase retimings, minor lane widenings and

	restriping, curbside parking regulation changes, etc.
Travel Behavior Inventory (TBI)	a set of surveys identifying travel patterns and characteristics of people and vehicles within the metropolitan area.
Travel Demand Forecasting (Modeling)	used to generate the average trip lengths for a region. The average trip length measure can then be used in estimating vehicle miles of travel, which in turn is used in estimating gasoline usage or mobile source emissions of air pollutants.
Travel Time Index	a measure of relative travel time. It is the ratio of the peak-period travel time to the travel time under ideal conditions. A Travel Time Index value of 1.3 indicates that peak-period travel takes 30 percent longer than under ideal conditions. Another way to think of this measure is as a "multiplier." That is, the value of the Travel Time Index is the amount you would multiply the "ideal" travel time by to get the actual travel time you experienced. Thus, "Travel Time Multiplier" would be an alternate name for this term.
Travel Time Reliability	the traveling public experiences large swings in congestion level, and their expectation or fear of unreliable traffic conditions affects both their view of roadway performance, and how and when they choose to travel. **Reliability** is commonly used in reference to the level of consistency in transportation service; and **Variability** might be thought of as the amount of inconsistency in *operating* conditions. Travel time reliability can be defined in terms of how travel times vary over time.
Travel Time	the amount of time, measured in the field, that it takes to traverse a given roadway segment.
Travel Demand Management (TDM)	strategies to manage demand on roadways designed to redirect trips to higher-occupancy modes or away from peak-traffic periods so that the total number of vehicles trips are reduced. TDM can include both capital and service improvements

	to highways and transit, and may involve community action.
Treadle	a pressure-sensitive device inserted in the pavement designed for directional counting of vehicle axles passing over them. These sensors are used as inputs to the lane controller to provide information on axle count and vehicle direction of travel, depending on the order in which the stripes are hit.
Trip	a single or one-directional vehicle movement.
Two-Way Left-Turn Lane (TWLTL)	a lane occupying the median area of an undivided roadway that extends continuously and is marked to provide a deceleration and storage area, out of the through traffic stream, for vehicles traveling in either direction to use in making left turns or accommodating left-turn movements from intersecting streets
United States Department of Transportation (USDOT)	the department of the federal government that includes the Federal Highway Administration (FHWA), Federal Aviation Administration (FAA), and the Federal Transit Administration (FTA). USDOT is headed by the Secretary of Transportation, a cabinet-level post.
Unstable Flow	this is representative of a breakdown in traffic conditions that occurs at the maximum flow boundary of level of service E. Unstable flow is characterized by the high density-low speed sides of the flow, speed, density curves.
Upstream	the opposite direction to which traffic flow is moving.
Urbanized Area	an area with a population of 50,000 or more designated by the U.S. Census Bureau, within boundaries that are identified by state and local officials, subject to approval by the Secretary of Transportation.
User Cost	the total dollar cost of a trip to a user for a particular mode of transportation. Includes out-of

	pocket costs such as transit fares, gas, oil, insurance, and parking for autos plus a valuation of implicit cost, such as waiting and travel times.
User Management	user management defines how and which types of users can utilize a facility, such as HOV occupancy requirements, access points, barrier separation, and user fees. Restrictions may vary by time of day or day of the week.
Value Pricing	a concept that uses monetary incentives to manage congestion during peak travel periods on tolled highways and crossing facilities.
Vanpool	an organized ridesharing arrangement in which 7 to 15 people travel together on a regular basis in a van. The van may be publicly owned, company owned, individually owned, leased, or owned by a third party. Expenses are shared and there is usually a regular volunteer driver. See also carpool.
Variability	the amount of inconsistency in *operating* conditions.
Variable Message Sign (VMS)	see Dynamic Message Sign (DMS)
Variable Speed Control	a system designed to optimize traffic flow on the freeway mainline by regulating the speed of vehicles on the facility.
Vehicle Delay per 100,000 VMT	the total vehicle delay in (vehicle-hours) divided by the amount of VMT. This is a relative measure of the total delay and will not be as affected by changes in the level of sensor instrumentation for a particular city.
Vehicle Hours of Delay (VHD)	a common measure of congestion on roadways; it is the sum total of delay experienced by all vehicles on the link, sub-network or network. Delay can be thought of as the difference between actual travel time and estimated travel time at free-flow travel speed, and is therefore a measure that is readily understood by the traveling public.

Vehicle Hours Traveled (VHT)	the total vehicle hours expended traveling on the roadway network in a specified area during a specified time period.
Vehicle Miles Traveled (VMT)	the measurement of the total miles traveled by all vehicles in a specified area during a specified time.
Vehicle Separators/Profilers	an AVI system component located on a gantry or at the side of a lane. They perform functions similar to light curtains. The class of vehicles is determined based on the profile of the passing vehicle.
Vehicle Trip	a one-way journey made by an auto, truck or bus to convey people or goods.
Vehicle-Hour	equivalent to one vehicle delayed for one hour.
Video Surveillance	the use of pan-tilt-zoom, steerable moving picture cameras to survey a toll plaza, ETC collection area, or a segment of roadway to monitor for incidents.
Volume-Demand-to-Capacity Ratio (V/C)	a measure that reflects mobility and quality of travel of a facility or a section of a facility. It compares roadway demand (vehicle volumes) with roadway supply (carrying capacity). For example, a V/C of 1.00 indicates the roadway facility is operating at its capacity. It is a common performance measure for MPOs and is widely used in congestion management and transportation studies.

LIST OF ACRONYMS Acronym Meaning

AADT Annual Average Daily Traffic
BPM Best Practice Model
CBD Central Business District
DAD Design Approval Document
HCM Highway Capacity Manual
HOV High Occupancy Vehicle
MAV Maximum Acceptable Volume
MPO Metropolitan Planning Organization
PHD Person Hours of Delay
PLAN Regional Transportation Plan
PPAQ Post Processor for Air Quality
PPCMS Post Processor for Congestion Management Systems
RCI Roadway Congestion Index
SED Socioeconomic Data
SIP State Implementation Plan
SOV Single Occupancy Vehicle
STIP Statewide Transportation Improvement Program
TAZ Transportation Analysis Zone
TCM Transportation Control Measure
TIP Transportation Improvement Program
TRI Travel Rate Index
TSM Transportation System Management
TTI Travel Time Index
UPWP Unified Work Plan
V/C Volume-Demand-to-Capacity Ratio
VHT Vehicle Hours Traveled
VMT Vehicle Miles Traveled